PLATE I.—Potomac Gorge at Harpers Ferry.

WEST VIRGINIA

GEOLOGICAL SURVEY

Jefferson, Berkeley, and Morgan Counties

By

G. P. GRIMSLEY, Assistant Geologist.

I. C. WHITE, State Geologist.

WHEELING NEWS LITHO. CO.
WHEELING, W. VA.
1916

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LETTER OF TRANSMITTAL.

To His Excellency, Hon. Henry D. Hatfield, Governor of West Virginia, and President, West Virginia Geological Survey Commission:

SIR:

I have the honor to transmit herewith the Detailed Report with accompanying topographic and geologic maps on the Counties of Jefferson, Berkeley, and Morgan. Together they comprise an area of 768½ square miles, known as the "Eastern Panhandle", which projects eastward beyond the main body of the State between the boundary lines of Maryland on the north and of Virginia on the south, in a manner similar to that of the Counties of Ohio, Brooke, and Hancock whose area constitutes the "Northern Panhandle" of West Virginia, projecting in a long narrow wedge between the States of Ohio and Pennsylvania.

This is the first of the Detailed County Reports to be published on areas lying east from the Alleghany Mountains, just ten years after the first County Report of the Survey had been issued on the three counties (Ohio, Brooke, and Hancock) of the Northern Panhandle. Many citizens residing eastward from the Alleghanies have thought that their mineral and other economic interests were being neglected by the State Survey in favor of the areas lying west from the Alleghanies, not knowing that causes entirely beyond the control of the State Geological Survey Commission, or the State Geologist, had operated to confine the detailed work of the Geological Survey to the western portions of the State. This delay in beginning county surveys east of the Alleghanies was due to the fact that no accurate topographic maps covering entire counties east from the Alleghanies were available, and without such maps as a base upon which to delineate geologic data, all geologic work is practically lost so far as its preservation and usefulness to the citizens of the area involved are concerned.

As it happened, when the cooperative topographic survey of the State was inaugurated in 1901, the State of Ohio had just begun cooperative topographic mapping along its southern or common boundary of Ohio and West Virginia, and as the quadrangle units (one-fourth degree square) which the Government Survey uses, pay no attention to State Lines, it was necessary that the West Virginia Commission accede to the request of the Ohio State Commission for cooperation in the Survey of the quadrangles that intersect the common boundary, or else lose many thousands of dollars in the cost of the work along the region of the Ohio River in taking up the Survey of partially completed quadrangles at a later date. The Superintendent of the West Virginia Survey could not consent to this waste of funds and time, since economy and efficiency have been the watchwords ever since he was placed in charge of the State Survey's activities in 1897, and hence as the work of a topographic survey must spread outward from points where it begins in order to accomplish its objects in an economic and efficient manner, there was no choice left but to continue the work eastward from where it first began (along the Ohio River), thus leaving the counties bordering the State of Virginia as the last ones to be surveyed topographically as well as geologically. This explanation is due the citizens of these eastern border counties who now for the first time will receive a volume of Reports and Maps prepared by the Survey on three of these eastern counties, since the cooperative topographic Survey of the State had made such progress eastward that it reached the border of Virginia at the southwestern portion of the same along the McDowell and Mercer County Lines four years ago, and hence during the season of 1914 a corps of topographers was put in the field to complete the surveys of Jefferson, Berkeley, and Morgan Counties, about half of whose areas had already been covered several years ago by the U. S. Geological Survey in a resurvey of quadrangles which overlapped from Maryland into West Virginia, without cost to the latter. There are many compensations which come to the counties whose surveys come last in any State, since the character of the surveys themselves tends constantly to improve in accuracy and in the addition of new features over those employed by the Government in its topographic work 10 to 15 years ago. Then, too, in the case of the three counties to be described in this volume, the delay enabled the Survey to secure the valuable services of a former Assistant of the Survey who had left it in 1910 for the more profitable field of private economic and professional service, and who for five years had resided at Martinsburg in the center of this Eastern Panhandle area which was also the center of his private economic work that had given him already great familiarity and knowledge of all the geologic formations and strata of the region. Therefore it was very fortunate not only for the economic interests of these three counties but also for the State as well that Dr. G. P. Grimsley consented to give a large portion of his valuable time to the preparation of the Detailed County Report herewith submitted for publication. Dr. Grimsley has devoted many years of time to the study of limestone deposits, and no one in the country is better prepared to classify and describe them. Hence the present volume describing an area in which probably exist the greatest and most valuable deposits of limestone and dolomites to be found in any like area of the United States, to say nothing of glass-sands, iron ores, and other minerals, should prove of vast economic importance not only to the Eastern Panhandle but to the entire State as well.

The immense thickness of these "Valley Limestones", amounting with their included shales to approximately 10,000 feet, is a revelation to most people, since prior to this detailed study of them they were not supposed to be more than 5,000 to 6,000 feet thick.

The estimate of Prof. Grimsley on page 474 of this volume for the quantity of very "low silica limestone" available down to a depth of only 100 feet from only one of the geological horizons; viz, the Upper Stones River beds, at 458,000,000 tons, is only a fraction of the enormous tonnage of pure limestones and dolomites that can be marketed from Jefferson and Berkeley Counties, while the quantity of other limestones useful in industry and of highest grade glass-sands available from Morgan County ledges, is beyond computation.

The impure semi-anthracite coals of Berkeley and Morgan Counties, occurring in the Pocono Formation below the true Coal Measures, are not now commercially valuable, but a century or two hence when most of the easily won coals of the Appalachian fields will be approaching exhaustion, these impure coals of Berkeley and Morgan may become of considerable fuel value.

The horticultural industries of this Eastern Panhandle area have grown immensely in value within the last few years, some of the largest and finest apple orchards in the country being located in this region, the apples, peaches, plums, pears, and other fruits produced in these counties being excelled by none.

The entire region described in this Report is replete with historic interest. Harpers Ferry, famous alike for its scenic beauty and as the site of John Brown's raid, the real beginning of the late Civil War, Charlestown, named after a brother of President Washington, where descendants of his brothers still reside, the mineral springs of Morgan County highly prized since colonial times for their health-giving waters, and Shepherdstown on the Potomac, celebrated as the place where Rumsey propelled the first steamboat of the world, are all within the area of the Eastern Panhandle.

To brother geologists some of the names used in this Report for the classification of geological formations may seem like returning to discarded ~~times,~~ terms but as these old and well-defined names of geologic formations first used by the Nestors of the Science in New York, Pennsylvania, and Virginia, are perfectly recognizable in West Virginia, the law of priority must govern, and hence neither Dr. Grimsley nor the Director of the West Virginia Geological Survey can find any valid reasons for substituting new and indefinite terms for old and well-named geologic formations, and therefore these new names, introduced without sufficient evidence of their necessity or of detailed studies of the rock formations they were intended to represent, will not appear in West Virginia's geological classification of the sedimentary beds.

I. C. WHITE, *State Geologist.*

Morgantown, W. Va.,
December 30, 1916.

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AUTHOR'S PREFACE.

The County Reports so far issued by the West Virginia Geological Survey have been descriptions of areas in the central and western portions of the State, where the most valuable mineral resources are coal, oil, and gas; and their geology, to a large extent, has been confined to the Carboniferous period.

The present Report is on an area beyond the mountains, on the three counties which form the extreme northeastern corner of the State, where the valuable minerals are no longer coal, oil, and gas, but limestones and sands. The geology dates further back in time, and includes formations from the oldest or crystalline rocks up into the early Carboniferous.

The preparation of the first of the County Reports of the State was allotted to the writer in 1905, on the Northern Panhandle Area, including the Counties of Ohio, Brooke, and Hancock. After a period of ten years, it seems almost a coincidence to have the privilege and pleasure of the preparation of the Eastern Panhandle Report on an area in which the writer has spent nearly seven years in the development and actual operation of the limestone industry.

The Eastern Panhandle Area is the oldest part of the State in its geology, and also in its history, rich in Indian and Revolutionary lore, for its rich limestone valleys were early centers of settlement. Washington and his generals frequently visited the area and became owners of large tracts of its lands, and a number of these famous war heroes of that day made here their permanent homes.

The area from that early day to this has been known for its agricultural resources, the fertile limestone soils yielding abundant and varied crops. In the three counties, with a population of 50,000, there are nearly a half million acres of farm lands whose value with equipment reaches $32,000,000. From its orchards, fruits of rich color and flavor are shipped to the ends of the earth. It is to-day the most prominent orchard section of the State and one of the best known in the

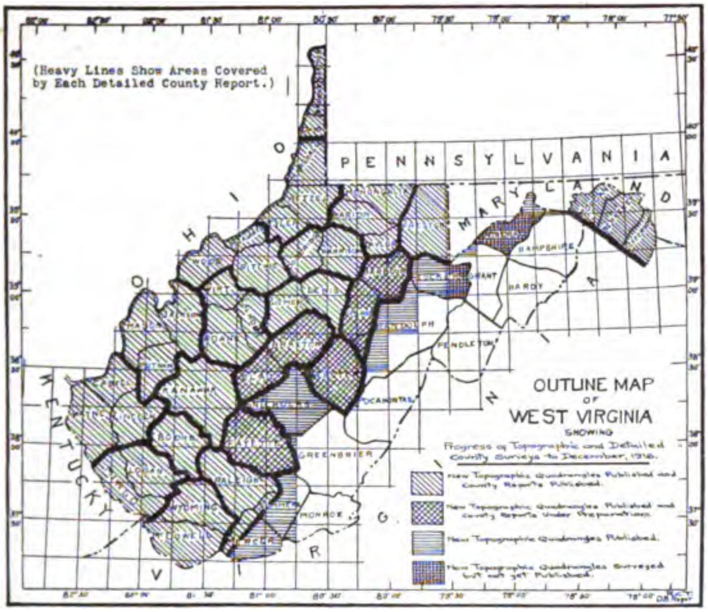

Figure 1.—See explanation on figure.

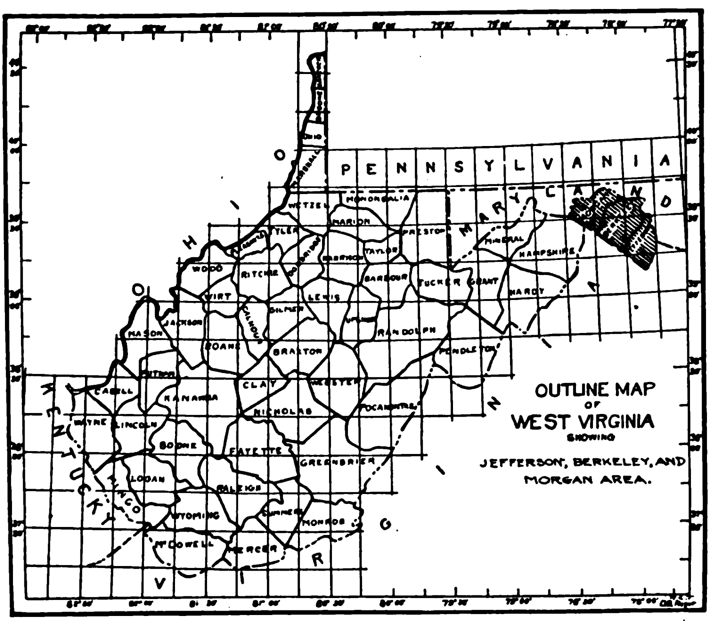

Figure 2.—See explanation on figure.

entire East, with over a million apple trees in addition to the large peach, pear, and plum orchards. Berkeley County holds first rank in the orchard industry of the State, Morgan is the great peach county of the State, and Jefferson has a rapidly growing orchard industry.

This Eastern Panhandle Area enjoys a mild and equable climate where zero winter and 100° summer temperatures are rarely recorded. The interval between killing frosts of spring and autumn represents a long growing season. Its mountain barriers protect the area from the severe storms which wreak their destruction from time to time to the east and west of this favored spot.

Topographically, these counties are located in the Appalachian Mountain area, including parts of the Blue Ridge, Great Valley, and Alleghany Ridges, with elevations ranging from 260 feet (the lowest point in the State, at Harpers Ferry) to 2,300 feet on Cacapon Mountain. Its terraced hills, ridges, and mountains reveal a most interesting story of land evolution which is discussed in detail in a special Chapter of the Report. It is an area where earth's forces have been most active in the geologic past, and the results of this work are shown in folds and faults of large size, and it is a region of very complicated structure.

The geological series within this area of 768½ square miles includes the only crystalline rocks in the State, and then passes through the different periods of the Paleozoic column up into the Pocono of the Lower Carboniferous. No area of similar size in the entire State contains so much of the geologic column.

The area contains a number of important economic mineral products. The glass-sands of Berkeley Springs are known for their purity throughout the eastern glass-manufacturing centers. The coal of Meadow Branch has attracted attention for nearly a century. This coal is shown by our analyses to be a semi-anthracite, with 86.14 per cent. of total carbon and with a heating value of 14,630 B. T. U. In selected specimens, it is equal to many of the anthracites of Pennsylvania, but it is so badly broken and intermixed with broken slate that its real value from a commercial standpoint is extremely doubtful.

In this area the natural conditions for the manufacture of Portland cement are ideal, with material shown by actual tests to be adapted to this work, with the necessary ingredients in great abundance and close together, nearness to large markets and tide-water, with low freights. Very few areas in this country offer the same advantages.

There is an abundance of shales and clays for brick and pottery, with only a single brick plant in the area in operation. These deposits are close to railroads, and the saving in freight rates to eastern markets would insure a large profit over the western plants now supplying this trade. Here could be made stoneware from tested clays near towns and railroad, and there is to-day only one such plant in the entire State. Complete tests on these shales and clays have been made in commercial laboratories, and also at the Pittsburgh testing plant of the Government. These results given in this Report should prove valuable in the development of this territory in this area.

Mineral waters of Berkeley Springs and Shannondale have been famous since the days of Washington, and their curative properties were recognized by the Indians. All over the area are valuable iron and sulphur springs not so well known. Springs of pure water are abundant and supply the farmer and the cities and towns. Many of the small settlements cluster around large flowing springs.

The predominant mineral product of the area is limestone. Berkeley and Jefferson Counties are almost covered with limestone suitable for various purposes. Near Martinsburg are large quarries and also large deposits of limestone as yet unopened, of the very pure limestone so low in silica that a hundred car-loads or more are shipped daily 230 miles to Pittsburgh iron and steel furnaces. The available market for this grade of stone is not far from six million tons a year. In the discussion of this high-grade limestone, it is shown by computation how this low silica Martinsburg limestone is actually worth at least 10 cents a ton more than the higher silica limestone now shipped to the Pittsburgh blast-furnaces from Pennsylvania quarries. We have estimated in this Report that approximately 458,000,000 tons of this grade of limestone are yet available in this district.

This pure limestone finds a large demand at the glass-manufacturing centers, where the rock must be as pure as possible. Berkeley Springs sand and Martinsburg limestone furnish the two most important ingredients for West Virginia glass. This glass industry is growing with wonderful rapidity in the western natural-gas areas of the State, and there is a corresponding increasing demand for these materials from Morgan and Berkeley Counties. The possible market for this limestone in glass plants is now about 250,000 tons a year. Its value for land fertilizer is being more and more appreciated by the farmers, and while this branch of the industry is not large at the present time, it will doubtless become very important in the future. The lime industry is large both in Berkeley and Jefferson Counties.

Ledges of dolomite of theoretical purity are quarried in Jefferson County near Millville, and car-load shipments are made as far as Canada. There are large deposits of this rock in this area awaiting development. Dolomites are found over the two counties that would be valuable for magnesian lime.

Marl, which represents a loose, unconsolidated carbonate of lime, is found along very many of the runs of the area, but this deposit is unused. In other States this material is regarded as most valuable for fertilizers, and the deposits are eagerly sought. The value of this material should be appreciated by the farmers.

The limestones over the three counties and more especially in Berkeley and Jefferson, afford materials for good roads near at hand. Model macadam roads are to be found all through the area, and others are now building. Jefferson County has for many years been famous for its roads. Its pikes extend to every part of the county and add to the prosperity of its residents as well as to their comfort. Berkeley County is now adding to its miles of stone roads. Marble and ornamental building stone can be found at many places over the area. This Eastern Panhandle Area has been richly endowed by Nature and it is an area of prosperity and a good country in which to dwell.

In the preparation of this Report, acknowledgments are due to many for kindly aid and cooperation. The United

States Geological Survey, Pawpaw-Hancock Folio (No. 179) by G. W. Stose and C. K. Swartz covers a large portion of the Morgan County area. Its descriptions and maps have been carefully studied. Extracts from this Report are acknowledged in the text, but much aid in mapping and in the identification of strata was derived from this Report and it has influenced and aided the writer in his work in many ways difficult to mention in detail.

To Mr. Stose is due the credit in first separating the great Shenandoah limestone complex into its integral parts. The writer has followed his classification of these parts and has been able to follow these divisions as a result of his study of this Folio as well as that of the Mercersburg-Chambersburg Folio of Stose (No. 170). The writer also had the pleasure and profit of being in the field with Mr. Stose in the Falling Waters and Hedgesville districts of Berkeley County for a short time. Mr. R. S. Bassler and Mr. E. O. Ulrich have also been very helpful in consultation on this work. The writer has been greatly aided by a study of the classic volumes on the Devonian published by the Maryland Geological Survey.

The various Government Departments have willingly cooperated in every way possible in this work. Mr. David White kindly identified the coal plants from the Meadow Branch Field. The U. S. Geological Survey members aided in the supply of data, advice on work, and use of illustrations from their publications. The Bureau of Standards made the tests on shales and clays at their Pittsburgh laboratory. The Office of Public Roads furnished data on road material tests previously made from this area, and also made tests on materials sent them by the Survey from this area. The U. S. Weather Bureau through H. C. Howe, Section Director at Parkersburg, has furnished the weather records for this Report, and Mr. George Van Metre, Observer at Martinsburg, also aided in the work of securing past records.

Quarry companies and a number of steel companies, who have made tests on limestone tracts in the area, have been liberal in the supply of data of their examinations and analyses. These analyses have added much toward the completeness of the Report. The analyses of samples collected over the area during this study have been made in the Survey laboratory by Mr. J. B. Krak under the direction of Professor B. H. Hite, Chief Chemist. These analyses have been made with their usual promptness and care, and can be depended upon in estimates of the value of tracts.

As in past Reports, so in this one, it is a pleasure to acknowledge the helpful aid of the State Geologist, Dr. I. C. White, who has given me the opportunity of preparation of this Report on a home region, and whose writings and suggestions have been of great help in the preparation of this volume. It would be difficult to estimate the value of his services given to this State through this Survey, so freely and without remuneration, "a labor of love" for his native State.

It is my hope that this volume may prove valuable in making known the valuable resources of this Eastern Panhandle Area, and that it may prove of service in the further development of its many valuable latent resources, and thus bring even greater prosperity to this section and thereby to the State.

G. P. GRIMSLEY.

Martinsburg, W. Va.,
July 1, 1916.

PART I.

The History, Physiography and Climate of the Eastern Panhandle Counties.

CHAPTER I.

THE HISTORICAL AND INDUSTRIAL DEVELOPMENT OF THE EASTERN PANHANDLE.

LOCATION AND HISTORY.

The eastern Panhandle of West Virginia includes the area which projects to the eastward over Virginia. It is bounded on the north and west by the Potomac River; on the east by the crest of the Blue Ridge which is the western line of Loudoun County, Virginia; on the south by Hampshire County, West Virginia, and Frederick and Clarke Counties, Virginia. It comprises an area of 768.45 square miles divided into the three counties of Morgan (231.26), Berkeley (324.78) and Jefferson (212.41).

The area of the three counties by districts, as calculated with planimeter by R. C. Tucker, is as follows:

	Square Miles
Jefferson County:	
Charlestown District	45.28
Harpers Ferry District	27.54
Kabletown District	52.04
Middleway District	45.62
Shepherdstown District	41.93
Total	212.41
Berkeley County:	
Arden District	41.57
Falling Waters District	30.80
Gerrardstown District	89.25
Hedgesville District	88.39
Martinsburg District	2.35
Mill Creek District	35.17
Opequon District	37.25
Total	324.78
Morgan County:	
Allen District	41.56
Bath District	20.43
Cacapon District	75.39
Rock Gap District	37.18
Sleepy Creek District	18.86
Timber Ridge District	37.84
Total	231.26

The topography in the western half of the area is mountainous, and in the eastern half is a great limestone valley. This topography is discussed more fully in the next Chapter, but the elevation above sea ranges from 260 feet at Harpers Ferry, the lowest point in the State, to 2300 feet on Cacapon Mountain.

The following resume of the history of these counties is based on a perusal of the histories of this valley by Samuel Kercheval (History of the Valley of Virginia, 1836), and Henry Howe (Historical Collections of Virginia, 1845), rare and most valuable historical works whose authenticity has never been questioned.

In the original distribution of counties in Virginia, the so-called "Wilderness" west of the Blue Ridge and extending to the Ohio River, formed the county of Orange established in 1720 to include the small portion of Spottsylvania County that extended across the mountain, and also all the remaining territory not before designated as a county.

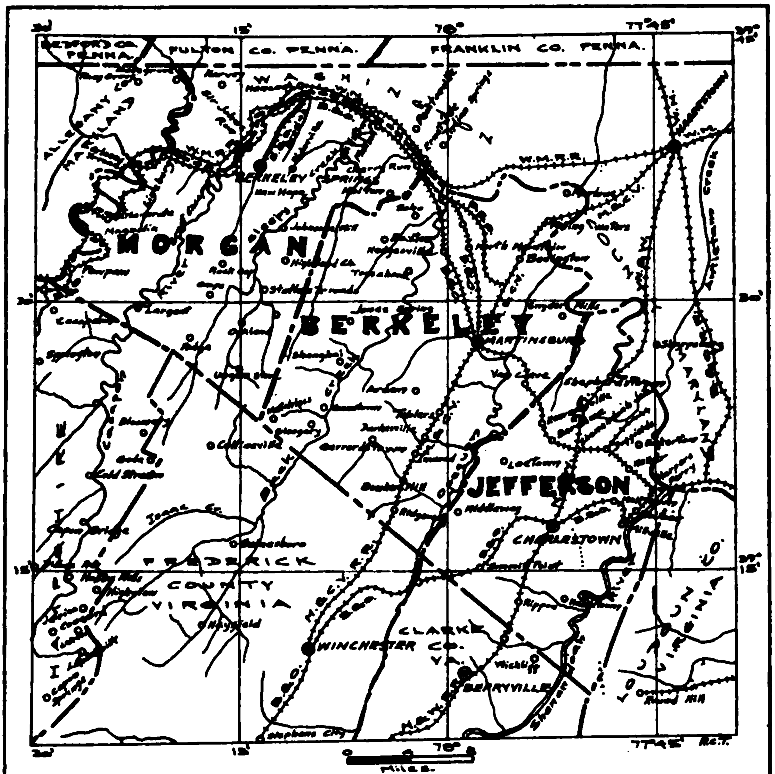

Figure 3. Map showing the Boundaries of the Eastern Panhandle Area, Railroads, etc.

In 1738 this vast tract was divided into two counties, Frederick and Augusta. Frederick County included the area bounded on the north by the Potomac, on the east by the Blue Ridge, and on the south and west by a line to be run from the head spring of Hedgman to the head spring of the Potomac. All the remainder of the territory west of the Blue Ridge formed the county of Augusta which was reduced to its present limits in 1790.

In May, 1772, Berkeley County was formed out of Frederick to include all the land between the Potomac and a line to be run from the intersection of Frederick and Loudoun Counties at a point one and a half miles north of the corner in Williams Gap, said line dividing the parishes of Frederick and Norborne, thence westward until it intersected the line of Hampshire County formed in 1754 and so the oldest county in the present State of West Virginia. The remaining portion of Frederick County was divided into Frederick and Dunmore Counties, the latter was changed in name in 1777 to Shenandoah. Berkeley County was named in honor of Governor Norborne Berkeley of Virginia. In 1801 Jefferson County was formed from a portion of Berkeley and named in honor of Thomas Jefferson. In 1820, Morgan County was formed from the western portion of Berkeley and a small part of Hampshire. It was named in honor of General Daniel Morgan of Revolutionary War fame.

Berkeley and Jefferson Counties are in the Great Valley whose discovery dates far back in the annals of history. This valley was a favorite abiding place of the Indians whose names still survive on many streams, as the Opequon, Tuscarora, Cacapon, Shenandoah, and the Potomac. The latter river was known by the Indian name of Cohongoruton and its south branch was the Wappatomaka which was shortened by Lord Fairfax to Potomac, and he applied this name to the whole river.

When the Valley was first known to the white people, the Indian tribes dwelling there were Shawnees near Winchester, the Tuscaroras near Martinsburg, with temporary encampments of the Catawbas from further up the Valley. The latter tribe was almost continually at war with roving bands of northern Delawares and savage battles were waged through the Valley and adjoining areas, notably at the mouth of Antietam Creek in 1736 and at Hanging Rocks in Hardy County. The favorite locations of the Indians were along the Shenandoah and its upper Forks, on the Opequon and its Tuscarora Branch.

The first record of the Valley being visited by white men was in 1710 when Colonel Alexander Spottswood, Governor of Virginia, with a troop of cavalry forced his way through the so-called impassable Blue Ridge Mountains and discovered the beautiful valley of the Shenandoah, an achievement which won him the honor of knighthood from the King. The first settlement, according to the late Virgil Lewis, was by Morgan Morgan, in 1727, who built his cabin at the present site of Bunker Hill. In 1732 Joist Hite and sixteen families from Pennsylvania came into the valley by way of York and settled south of Winchester, though this town was not settled until 1738, and established as a town by Legislative Act until 1752.

The first town in the Valley and also the oldest town in the present State of West Virginia was settled by German mechanics at Shepherdstown under the name of Mecklenburg under a grant to Richard Morgan in 1732. The town of Mecklenburg was established by Legislative Act in November, 1762, at the same date as the establishment of Romney in Hampshire County. It was laid off in lots and streets by Captain Shepherd whose name it was later given. This town is noted as the home of the inventor of the first steamboat, James Rumsey, whose boat was propelled by steam alone, seventeen years before the successful experiments of Fulton on the Hudson. His experimental work is described by Howe (p. 339) as follows:

"In September, 1781, it appears from a letter of his (Rumsey) now before us, that he was employed by the Potomac Company, of which Washington was a member, to improve the navigation of the Potomac River. In the summer of the year 1783, he directed his attention to the subject of steamboats; and in the autumn of 1784 succeeded in a private but very imperfect experiment, in order to test some of the principles of his invention. In the October session of that year, he obtained the passage of an Act from the Virginia Assembly, guarantying to him the exclusive use of his invention in navigating the waters of that State, for the space of ten years from date. In January, 1785, he obtained a patent from the General Assembly of Maryland for navigating their waters. Through the whole of this year he was engaged in working at his boat, but it was not ready for public trial until 1786, the year following. In this experiment he was eminently successful. He succeeded in propelling his boat, by steam alone at Shepherdstown, against the current of the Potomac, at the rate of four or five miles an hour."

Howe further quotes (p. 339) a description of this first steamboat from an English work by Stuart, as follows:

"Rumsey's boat was about 50 feet in length, and was propelled by a pump worked by a steam engine which forced a quantity of water up through the keel; the valve was then shut by the return of the stroke, which at the same time forced the water through a channel or pipe, a few inches square, (lying above or parallel to the kelson), out at the stern under the rudder, which had less depth than usual, to permit the exit of the water. The impetus of this water forced through the square channel against the exterior water, acted as an impelling power upon the vessel. The reaction of the effluent water propelled her at the rate above mentioned, when loaded with three tons in addition to the weight of her engine, of about a third of a ton. The boiler was quite a curiosity, holding no more than five gallons of water, and needing only a pint at a time. The whole machinery did not occupy a space greater than required for four barrels of flour. The fuel consumed was not more than from four to six bushels of coal in twelve hours. Rumsey's other project was to apply the power of a steam engine to long poles, which were to reach the bottom of the river, and by that means to push a boat against a rapid current."

As early as 1738, the Quakers had formed a settlement on Apple Pie Ridge to the west of Martinsburg. There were also early settlements on Cacapon River, Lost River, Back Creek, and on the Opequon. A Baptist settlement under Rev. John Gerrard was established on the Opequon about 1742. At this time the Valley from the Blue Ridge to North Mountain was described as a vast prairie barren of timber, and a great pasture with various kinds of wild animals, buffalo, deer, bear, etc.

The early days of the white settlers were filled with great danger from hostile Indians, and the annals of these days include accounts of massacres, battles, and the erection of forts for the protection of settlers, conditions which greatly deterred the settlement and development of the Valley. In 1754 by a treaty, the Indians moved west of the mountains and the area enjoyed a period of peace until after the French and Indian wars with the defeat of Braddock in 1766, when Indian depredations and massacres were again chronicled in the Valley, and the Indian danger again became a source of terror by night and by day. Finally Governor Dunmore raised an army in the lower Shenandoah Valley, and General Andrew Lewis in the upper portion of the Valley, and Dunmore's War came in 1774 with the defeat of the Indians in the Ohio Valley, but the war was not closed until Wayne's victories in 1794, when permanent peace and freedom from Indian attacks resulted. In the meantime the War for American Independence came and ended with the surrender of Cornwallis at Yorktown on October 19, 1781.

Next came the second war with Great Britain in 1812, and both these wars drew their quota of brave men from this

Valley. The era of peace following these wars brought in new people and new settlements and the development of the Valley made good progress. In 1800 there were 22,000 people in the eastern Panhandle area; and in 1840, 38,307, and over 1,800 scholars in the schools.

In October, 1859, the peace of the Valley was again disturbed when John Brown, of Kansas, took possession of Harpers Ferry and in less than 18 months the whole country was in the throes of a Civil War. The majority of the people in this area was friendly to the South, casting their lot with it, and hence the Valley became one of the great centers of the War with its concurrent devastation of life and property. While no great battles were fought in the eastern Panhandle area, it was an almost continual scene of skirmishes and was alternately in control of the North and the South.

In April, 1861, the Ohio River counties called a convention at Wheeling which was followed by a second call and at that city on June 19, 1861, an ordinance was passed for the separation from the mother state and an organization of a new state government, with the result that West Virginia was admitted to the Union as a new State on June 20, 1863. The counties of Berkeley and Jefferson were not included but were annexed during that year. This annexation led to a legal fight as the two counties were claimed by Virginia, and the case was finally settled by a decision of the United States Supreme Court in 1871 in favor of West Virginia and the two counties then became members of the new State. Frederick County, Virginia, was also expected to join the new State and was granted the right to vote upon this measure but no election was ever held.

HISTORY OF TRANSPORTATION.

THE RIVERS.

In the early days projects were advanced for the improvement of the Potomac and the Shenandoah Rivers for transportation. During high waters rafts and logs were floated down the branch streams to the Potomac and thence down this river and also down the Shenandoah, but they were never used for regular boat trips on account of the low depth of water and the numerous rapids. In 1785 the Government authorized the clearing of the Potomac of rocks at Harpers Ferry, but in all these plans no special work was done, and the rivers were regarded as of very doubtful value in transportation.

TURNPIKES.

In the early days of the settlements of Virginia in the portion now included in West Virginia, there were no roads across the mountains but their need was soon recognized and State roads were constructed from the east to the west. Later private companies were authorized to build pikes on which toll could be charged and the State subscribed for so much stock, usually three-fifths of the authorized capital required.

The first one to be built through Government aid was the National Road from Washington to Cumberland, then extended to Wheeling and into Ohio. The bill for this road was passed by Congress in 1802 and its construction began in 1811, reaching Wheeling in 1818. A stage line on the road in 1836 made the trip from Washington to Wheeling in three days, which was regarded as very fast time. The traffic increased until there was an almost continuous line of stages and wagons, a condition which lasted until the Baltimore and Ohio Railroad was completed to Wheeling near the end of the year 1852, and in a few months the days of the stage coach and freight wagons were doomed on this road and they soon disappeared from view. This great highway was reached from the northeastern part of the West Virginia area by roads built to Hagerstown.

Kercheval writing at this time described some of these new roads in 1833 (p. 372) as follows:

"A turnpike road from Winchester to Parkersburg, on the Ohio River, a distance of about two hundred and eighty miles, has lately been finished, and another macadamized turnpike road from Winchester to Staunton has just been put into operation, and it is almost inconceivable what vast quantities of produce now find a ready way to Baltimore from the increased facilities of our improved roads to that market.

"An improved road from Staunton across the Alleghany Mountains is now going on to Parkersburg, which will add great facilities to

Valley trade, to greatly enhance the value of real estate in western Virginia. There is also a turnpike from Harrisonburg by way of the Warm Springs, Hot Springs, and White Sulphur, across the Alleghany and Wyandotte, by way of the Kanawha. These several turnpikes are passable at all seasons of the year, and have greatly expedited the passenger's journey from east to west. These several turnpikes have been made at vast expense to the State and stockholders, notwithstanding which, improvements are still going on. A few years more and western Virginia will vie with our northern and sister States with her vast improvements."

This Staunton and Parkersburg Turnpike, described by Kercheval, was chartered in 1823-4, and the Winchester and Parkersburg Pike, known more commonly as the Northwestern Turnpike, was built in 1831, passing through Hampshire, Mineral, and Grant Counties, thence northwest and finally southwest, reaching Parkersburg in 1838. This road became a busy thoroughfare from the east to the west and the reverse. and it had a very great influence on the development of the interior and western portions of the State, but like the National Road its traffic gave way before the steam transit of the Baltimore and Ohio Railroad which reached Cumberland in 1842 and Parkersburg in 1857.

In March, 1851, the Berkeley and Hampshire Pike was chartered to run from Martinsburg via Boyds Gap in North Mountain and Bloomery Gap to a point on the Northwestern Turnpike at or near French's Tavern, a total distance of 45½ miles, and it was completed in 1858, and thus brought this artery of traffic available to the eastern Panhandle area.

In 1838 and revived in 1848, a charter was issued for the Martinsburg and Winchester Turnpike, which began at Martinsburg and connected with the Northwestern Pike at Winchester. To complete the line northward to the river, the Martinsburg and Potomac Pike was chartered in 1849 to extend the Winchester Pike to a point on the Potomac River opposite Williamsport. These three pikes are among the few toll roads in the State at the present day.

Other turnpikes authorized by the Acts of the Virginia Legislature were, the Shepherdstown and Smithfield; Smithfield, Charlestown, and Harpers Ferry; Hedgesville and Potomac, in 1850; Berryville and Charlestown, in 1847; Jefferson and Frederick, in 1851; Middleway and Gerrardstown; Hampshire and Morgan County, in 1849; Sir Johns Run; Winchester and Berkeley Springs; and a number of others whose records are overlooked. The period from 1838 to 1851 was one of turnpike construction for the purpose of opening a vast interior country. The beneficial results of these branching routes on the development of the country tributary to them would be very difficult to estimate but they were certainly very great.

In June, 1850, the Chesapeake and Ohio Canal was completed from Washington to Cumberland, and this soon became an important route for shipments and was a great step in advance over the highway routes. It follows the north bank of the Potomac in Maryland around the border of the eastern Panhandle area. This canal was thus accessible to this area and had much influence on its trade development.

RAILROADS.

The first railroad in the eastern Panhandle area was the Winchester and Potomac, chartered in April, 1831, and which ran from Winchester via Charlestown to Harpers Ferry. It was later leased to the Baltimore and Ohio Railroad and later purchased by it, and extended southward and at the present time is known as the Valley Branch of the main system. The original charter was for 12,000 shares at $25 each, or a total of $300,000.

Baltimore and Ohio Railroad.—The National Road was a most important source of freight and passenger traffic for many years to the cities of Washington and Baltimore, but with the building of the Erie Canal about 1825, much traffic was diverted to the north and it was found to be impracticable to complete the Cumberland Canal to the Ohio. Thus was Baltimore's trade threatened, and in order to hold her prestige in trade a meeting of business men was called in Baltimore on February 12, 1827, to consider plans for a railroad from Baltimore to the Ohio River. A week later a plan for the organization of the Baltimore and Ohio Railroad was formulated. A committee was appointed to secure an act of incorporation from the Legislatures of Maryland, Virginia, and Pennsylvania. This Act was passed by the Legislature of Maryland on March 8, 1827, appointing nine commissioners and fixing the capital stock at $3,000,000 in 30,000 shares of $100 each, but with the reservation that 10,000 shares be held for purchase in the State of Maryland, and 5,000 shares reserved for the purchasers in the City of Baltimore, for a period of twelve months, while the remaining 15,000 shares could be sold out of the State.

The original plan of the road was to follow along the Shenandoah River from Harpers Ferry to the headwaters of the Kanawha, thence down the Kanawha to the Ohio River, but the Virginia Assembly refused to grant this route and placed the Ohio River terminus at any point north of the mouth of the Little Kanawha River (Parkersburg).

The Board of Directors was organized April 23, 1827, and the surveys were completed in 1828. The corner-stone of the road was laid July 4, 1828, by Charles Carroll of Carrollton, and the capital stock was increased to $5,000,000. The first cars were drawn by horses with daily trips between Baltimore and Ellicott City, the first trip being made May 24, 1830, and in August of that year a model of a locomotive was used by Peter Cooper on this road.

The line was completed to Frederick, Maryland, on December 1, 1831, to the Point of Rocks on the Potomac in April, 1832, reaching Harpers Ferry December 1, 1834, there connecting with the Winchester and Potomac Railroad. From this date to 1838, Virginia refused to grant the right to construct westward, but that year granted the right on the condition that Wheeling be made the terminal point. Construction work began again in 1840, and the road reached Martinsburg in 1841-2, and was completed to Cumberland November 5, 1842.

In 1842 work was started on the engine house and shops at Martinsburg. No further work on the road was done until 1849, when construction was resumed westward and completed to Wheeling January 1, 1853. It is stated by Callahan in his Centennial History of West Virginia (p. 112) that this extension to Cumberland increased the yearly earnings from

$391,070 in 1842 to $575,205 in 1843, and to $658,619 in 1844. The Parkersburg Branch was completed in 1857, and from Wheeling to Pittsburgh in 1871. The road reached Newark. Ohio, in 1849, and Columbus, Ohio, in 1850. At the present time this railroad has 1,071 miles of track in the State and the total mileage of all the different railroads in West Virginia is 3,556.

The building of this railroad was of the greatest benefit to the State of western Virginia and resulted in marked development starting almost at once. It was for many years the main route from East to the West. It brought in new people and the small settlements along the line grew into cities, manufactures sprang up here and there, and the products of mine, forest, and farm found an outlet. The natural destination of these products was at the eastern terminus and Baltimore became the trade center for western Virginia and the country to the west, which position it has been able to maintain to the present day. Those early founders accomplished their purpose and not only prevented the deflection of trade from the north by the Erie Canal route, but added a vastly greater new trade.

The new railroad enabled a scattered mountain and valley people over the large area of the State to be brought together with a resultant intermingling of interests and the community spirit was built up, resulting in unity and strength of the population and in the greater strength of the common interests of a State. Callahan says in his History that "The parts of country which it touched, it bound together into a closer social and political union than had before been realized. It was a large factor in determining the political destiny of West Virginia, the military strategy of the Civil War, and the continued integrity of the American Union."

Cumberland Valley Railroad.—On February 19, 1868, a charter was issued the Martinsburg and Potomac Railroad to build a line from the Potomac River opposite or near the town of Williamsport through the town of Martinsburg to the Virginia State Line. There were issued 15,000 shares of the capital stock of $100 each. This line was to be built for the purpose of connecting with the Franklin Railroad of Pennsylvania which ran from Chambersburg to Hagerstown and Williamsport. The new railroad was completed to Martinsburg in 1873.

The road was sold on November 17, 1887, and purchased by Mr. Thomas B. Kennedy; and on March 17, 1888, a new company was organized under the name of Cumberland Valley and Martinsburg Railroad and that year began an extension to Winchester which was reached in October, 1889, operating in Virginia under the name of Martinsburg and Potomac. In December, 1889, authority was granted for the consolidation of the road in Virginia and the one in West Virginia under the name of Cumberland Valley and Martinsburg, which was done early in 1890. The certificate of the Cumberland Valley Railroad of Pennsylvania, the successor of the Franklin Railroad, was recorded in West Virginia June 11, 1901.

This railroad is a division of the Pennsylvania System and is said to be the only division of that system operated under a separate executive staff, a tribute to the successful management and ability of its President, Mr. M. C. Kennedy. The length of the line from Winchester to the Potomac is 46 miles, of which 24½ miles are in Berkeley County. At the river, it crosses on a new steel bridge completed in October, 1914, replacing the old bridge. Many improvements in alignment and grades were made at the same time. Across the river, it connects with the Cumberland Valley of Pennsylvania, extending to Harrisburg, where it connects with the main lines of the great Pennsylvania System.

Norfolk and Western Railroad.—The Shenandoah Valley Railroad was built in 1879 and operated in March, 1880, from Shepherdstown via Front Royal to Bentonville, a distance of 54 miles, and completed that year to Hagerstown. It appears to have had a successful course for a time, but becoming involved in Court proceedings, was sold to the Norfolk and Western in 1881, and completed to Roanoke, Virginia. It extends through Jefferson County from Shepherdstown via Charlestown to the southern line of the county, crossing the Baltimore and Ohio main line at Shenandoah Junction. The length of this line from Roanoke to Hagerstown is 239 miles, and the length in Jefferson County is 17½ miles.

Western Maryland Railroad.—The Western Maryland Railroad from Baltimore to Cumberland on its way west to the coal fields of West Virginia and to Connellsville and Pittsburgh, follows the Potomac River on the Maryland side from west of Williamsport to beyond Pawpaw. It crosses the western portion of Morgan County, where it cuts across the bends of the Potomac west of Doe Gully and west of Magnolia, and to the northwest of Pawpaw, with a total length in the county of 6½ miles, though its mileage in the State of West Virginia is 197. The **Williamsport, Nessle and Martinsburg Railroad** connects at Charlton with the Western Maryland Railroad, and extends south of the Potomac in Berkeley County and it is surveyed to Martinsburg.

GENERAL DESCRIPTION.

MORGAN COUNTY.

Morgan County, forming the western portion of the eastern Panhandle, has an area of 231.26 square miles. It is bounded on the north and west by the Potomac River, separating it from Allegany and Washington Counties, Maryland; on the east by Berkeley County; on the south by Hampshire County, West Virginia, and Frederick County, Virginia. It was named in honor of General Daniel Morgan. The county was formed from the western portion of Berkeley and the part of Hampshire County west of the Warm Spring Ridge. It was formed February 9, 1820, under the following Act of the Virginia Assembly:

"Be it enacted:—That all that part of the counties of Berkeley and Hampshire contained within the following bounds, to wit:—beginning at the mouth of Cherry's Run at the river Potowmac in the county of Berkeley, thence up the middle of said Run to its source, thence due west to the top of Sleepy Creek Mountain, thence along the top of said mountain to the line that separates the counties of Frederick and Berkeley, thence with the said line to the county of Hampshire, thence in a direct line until it strikes the river Potowmac opposite Mitchels Rock, and thence by the river Potowmac to the beginning, shall form one distinct and new county, and be called by the name of Morgan."

The following **post-offices** were established in the county before the days of rural delivery, and they now represent centers of small settlements:

Berkeley Springs.	Oakland.	Rock Gap.
Brosius.	Ompa.	Sir Johns Run.
Cherry Run.	Orleans Crossroads.	Sleepy Creek.
Great Cacapon.	Pawpaw.	Stotlers Crossroads.
Magnolia.	Ridge.	Ungers Store.
		Woodrow.

Only two of these are incorporated towns, Berkeley Springs and Pawpaw; the former had a population in 1910 of 864, and the latter had 725. The other places usually consist of a store and a few houses, being larger on the railroad. Cherry Run is an important terminal point for the transfer of freight to the Western Maryland Railroad from the Baltimore and Ohio. Brosius is the Hancock station on the latter railroad. Ungers Store is a distributing point to the upper part of the county and back portions of Hampshire. Pawpaw is central to a rapidly growing orchard section, and has a large tannery, with a capacity of 400 hides daily. Morgan County has become one of the important peach and apple orchard sections of the State and a large quantity of fruit is shipped each year. It is also an important canning center, there being at the present time 25 canneries with an output of 200 car-loads a year, working mostly on tomatoes for which its soil and climate seem to be especially adapted.

Berkeley Springs.

Berkeley Springs is the county seat and it is the center of a large glass sand industry which will be described in detail in a later chapter on mineral industries. The town has been a resort for invalids from early days on account of the Warm Springs which issue from five places under the ridge back of the town. These springs were highly prized by the early Indians, and Washington made note of them in his journal in 1747. The water has a uniform temperature through the year of 70 to 74 degrees Fahrenheit, and contains lime carbonate, sodium chloride, magnesium sulphate, and lime silicate. The park with the springs is the property of the State and the place is equipped with bath-houses and swimming pools. This was one of the early white settlements and the town was established on the lands of Lord Fairfax in October, 1776, by the following Act:

Preamble. "Whereas it has been represented to the General Assembly that the laying off of 50 acres of land in lots and streets for a town at the Warm Springs in county of Berkeley, will be of great utility, by encouraging the purchasers thereof to build convenient houses for accommodating numbers of infirm persons, who frequent those springs yearly for the recovery of their health; Be it enacted, etc., that 50 acres of land adjoining the said springs, being part of a larger tract of land, the property of the right honorable Thomas Lord Fairfax, or other person or persons holding the same by a grant or conveyance from him, be and the same is hereby vested in Bryan Fairfax, Thos. Bryan Martin, Warner Washington, the Rev. Charles M. Thurston, Robert Rutherford, Thos. Rutherford, Alexander White, Philip Pendleton. Samuel Washington, Wm. Van Swearingen, Thos. Hite, Jas. Edmundson, and James Nourse, gentlemen, trustees, to be by them, or any seven of them, laid out into lots of one quarter of an acre each, with convenient streets, which shall be and the same is hereby established a town, by the name of Bath.

"And be it farther enacted, That all the said Warm Springs except one large and convenient spring suitable for a bath, shall be, and the same are hereby vested in the said trustees, in trust, to and for the publick use and benefit, and for no other purposes, whatsoever."

At the present day, Berkeley Springs is a town of about 864 people, with railroad connection by a branch road to the main line of the Baltimore and Ohio at Hancock Station. It is still a popular resort and the springs seem to possess valuable curative properties. It is a scenic spot and has a number of good stores, banks, hotels, fine residences, weekly newspapers, and the glass sand works give employment to a considerable number of people. It is the natural outlet for the trade and supplies in and out of the eastern part of the County.

BERKELEY COUNTY.

Berkeley County is the portion of the original county left after Morgan and Jefferson were separated from it. The county has an area of 324.78 square miles, and is bounded on the north by the Potomac River, separating it from Washington County, Maryland; and on the east by Jefferson County; on the south by Frederick County, Virginia; and on the west

PLATE II.—Martinsburg Power Company Plant on the Potomac River near Shepherdstown.

by Morgan County. It was named in honor of Governor Norborne Berkeley in 1768. Its population was 21,999 by the census of 1910. Its resources are orchards, farm products, and limestone. It is one of the greatest centers in the United States for high-grade, pure, fluxing limestone for iron and steel furnaces, an industry that amounts to a half-million dollars a year, and which is described in detail in the Chapter on Mineral Resources. It is one of the richest farming sections of the State, with over 1,270 farms, and most of its area is laid out in farms and orchards.

Orchard Industry of Berkeley County.—The orchard industry of Berkeley County began at an early date. Professor Alderman in the Semi-Centennial History of West Virginia (p. 342) gives some interesting early history of this industry and quotes a lease of George Washington made March 18, 1774, in which he leased 125 acres of land in Berkeley County and among other things specified,

> "That within seven years an orchard of one hundred winter apple trees at 40 feet distance every way from each other and that one hundred peach trees shall be planted on some convenient part of the said demised land, and the same to be kept always during the continuance of said term well pruned, fenced in and secured from horses, cattle, and other creatures that may hurt, and if any of the said trees shall die, decay, or be destroyed that others of the same kind shall be planted in their place, and the entire number thereof shall be kept up during the said term."

At this early day, the value of orchards was appreciated and the soil and climate were regarded as especially favorable in this section. From that day to this there has been an apple industry in the section, becoming more and more prominent annually.

According to the authority quoted above, the father of commercial fruit growing in this eastern area was W. S. Miller of Gerrardstown, who as early as 1851 planted sixteen acres of apples, peaches, and plums. By the close of the Civil War, he had 4,000 bearing peach trees. By 1901, he had 4,000 apple trees, 25,000 peach trees, and large numbers of plum, pear, quince, and cherry trees. The orchard interests of the Millers, sons of the founder of this industry, are the largest in the eastern Panhandle, including nearly 12,000 acres with over a half-million trees.

In 1900, there were in the county, 114,802 apple trees, 8,777 pear trees, 126,422 peach trees, 1,423 cherry trees, 15,441 plum trees, and the total value of the fruit crop that year was $152,465. At the present time the county has 11,700 acres of apple orchards on which there are 580,000 trees, one-half of which are in bearing. There are also 150,000 peach trees, and 20,000 pear trees. The county holds first rank in apple production in the State. The varieties of apples grown in this section are as follows: Northwestern Greenings, Black Twig, York Imperial, Ben Davis, Stayman Winesaps, Grimes Golden, Gano, Baldwin, Wolf River, and Jonathan. The orchards are carefully cultivated and sprayed only three times a year, while in the West, four to seven sprayings are required. The freight rates to eastern markets and tide-water are very low compared with those from orchards in the West. The rates are 27 cents a barrel to New York, 17 cents to Pittsburgh, and 42 cents to Chicago. The flavor and color are said to be superior to many western sections. The market for the eastern Panhandle fruit is expanding each year and many car-loads are shipped to foreign countries. Orchard investments are most highly regarded and some very large companies are engaged in the work. One orchard of 80 acres and 6,000 trees shipped nearly 1,800 barrels one season, and over half the trees were too young for that season's bearing. Another orchard of 250 acres and 11,537 trees shipped 20,000 barrels, which yielded a return of $150 per acre for that year. Returns are reported as high as $200 per acre.

A detailed survey of the apple orchards of Berkeley County was made in 1912-13 by E. C. Auchter for the State Agricultural Experiment Station (Bulletin 151). From this report it is found that nearly one-third of the total acreage of apples in the county is found in the Back Creek Valley, west of North Mountain, also two-thirds of the peach trees, and over one-half of the pear acreage.

The largest apple yields come from orchards 19 to 22 years old, and the orchards are bearing from 8 to 10 years old. These orchards range in size from 5 to nearly 500 acres. Of the 583,657 apple trees, 60 per cent. are not yet bearing. 94 per cent. of the trees have been planted in the last eighteen years. 44 per cent. were planted from 1909 to 1913. There are over thirty companies with orchards over 100 acres in size, and there are nearly 250 orchards and one-fourth of these are 10 to 19 acres in size.

The average yield per acre in 1912 was 34.8 barrels and the average price was $2.13 a barrel. It is estimated that it costs $1.25 to produce and sell a barrel of apples. The average yield per acre for three years, 1910, 1911, and 1912, was 40.2 barrels, which were sold at a profit of one dollar per barrel, or a net profit of $40.20 per acre. 38 per cent. of the orchards in this period returned over $100 per acre and eight ran over $200.

The National Magazine in discussing the orchard industry of West Virginia (December, 1913) states that, "To the person who wishes to engage in the fruit business, West Virginia offers inducements equalled by no other State in the Union. To the eastern shipper and exporter particularly, the quality of fruit, the nearness to base of supply and the shortness of the haul and consequent low freight rates, West Virginia affords the best marketable opportunities."

The following **post-offices** were once established in the county, though most of these have been discontinued since the rural free delivery system was inaugurated, but they represent the settlements over the county:

Allensville.	Ganotown.	Martinsburg.
Arden.	Gerrardstown.	Matchless.
Baxter.	Glengary.	North Mountain.
Bedington.	Hedgesville.	Ridgeway.
Bunker Hill.	Inwood.	Shanghai.
Darkesville.	Jones Spring.	Soho.
Falling Waters.	Little Georgetown.	Tablers.
Foltz.	Marlowe.	Tomahawk.
		Van Clevesville.

In addition, there are the new towns at Berkeley and Blair near the limestone quarries. Some of these small towns have a very old history and were established by Acts of the Virginia Assembly. **Darkesville** was laid out in lots and streets on the land of James Buckells in October, 1791, and was named

Buckellstown. It was later named Darkesville in honor of Gen. Darke who lived in that section. It is mentioned in the records of 1835 as containing some thirty houses.

Gerrardstown was established by legislative Act in 1787 as Middletown and later named in honor of an early Baptist minister, Rev. John Gerrard. **Hedgesville** was founded in 1830 by Hezekiah Hedges, and is located near the site of old Fort Hedges of the days of Indian warfare. It is an incorporated town of about 400 people and located one mile west of North Mountain Station on the Baltimore and Ohio Railroad. **Bedington** is the location of large watercress farms, and a famous sulphur spring is located in a grove just east of the town. Most of the other towns and settlements are the centers of farming districts.

Martinsburg.

Martinsburg, the county seat, was established as a town in October, 1778, by the following Act of the Virginia Assembly:

"Whereas it has been represented to this present General Assembly, that Adam Stephens, Esq., had lately laid off one hundred and thirty acres of land in the county of Berkeley, where the court house now stands, in lots and streets for a town, etc.; Be it enacted, etc., that the said one hundred and thirty acres of land laid out in lots and streets, agreeably to a plan and survey thereof made, containing the number of two hundred and sixty-nine lots, as, by the said plan and survey, relation thereunto being had, may more fully appear, be and the same is hereby vested in Jas. McAlister, Joseph Mitchell, Anthony Noble, Jas. Strode, Robert Carter Willis, Wm. Patterson, and Philip Pendleton, gentlemen, trustees, and shall be established a town by the name of Martinsburg."

The town was named Martinsburg by General Stephens in honor of his friend, Col. T. B. Martin. It is described by Kercheval in 1836 as a town of 1,700 people, with two newspapers, seven stores, market house, and six churches. At the present time, it is the sixth city in the State in population, with over 10,000 people. In 1860, its population was 3,000, increasing to a little over 6,000 in 1880. It is the shipping center for the products of the county, and for the orchards and farm products, with two railroads. It was formerly a division point on the Baltimore and Ohio and was the location of the division shops, but the division point was removed in 1895.

Among its varied industries was the Hannis Distillery Company, established in 1867, though the first distillery was located here in 1800 and enlarged in 1857, but destroyed during the Civil War. The main building covers an area of 185 by 119 feet, with five additional warehouses, and its daily capacity was 60 barrels. The buildings are of stone and they housed the most modern stills, mills, condensers, etc., and made a specialty of pure rye whiskey. By the Prohibition law in effect July, 1914, the work ceased at this plant.

There are two modern flour mills with a daily capacity of 250 barrels of flour. The Tuscarora foundry was established in 1848 and its stone building, 40 by 112 feet, is equipped for engine work, castings, and general repair work. The quarries of the section depend very largely on this plant for their repairs. The city is supplied with artificial gas by the Martinsburg Gas Company which has two gas holders with over 50,000 feet capacity. Electric light and power are furnished by the Martinsburg Power Company from its two water power generating plants on the Potomac and by a steam auxiliary plant in town. Power is also furnished to the quarries by the Northern Virginia Power Company, whose offices are in Winchester and its power plants in Morgan and Jefferson Counties.

There are two woolen mills and the two large plants of the Interwoven Knitting Mill Company, and the Auburn Wagon Works. The mills and factories give employment to over 2,000 people, while the quarries employ about 1,200. There is thus a large bi-weekly payroll and a prosperous business condition. In the city are two daily papers, large and complete stores of various kinds, and five banks, also one of the best hotels in the Valley.

The U. S. Census for 1914 gives the following statistics on the manufacturing industries of Martinsburg:

Number of establishments	37
Wage earners	1,568
Capital invested	$2,630,000
Wages paid annually	719,000
Value of products	3,022,000

JEFFERSON COUNTY.

Jefferson County was cut off from the eastern portion of Berkeley in 1801. It is the most eastern county of the State and has an area of 212.41 square miles. It is bounded on the north by the Potomac River, which separates it from Washington County, Maryland; on the east, it is separated from Loudoun County, Virginia, by the Blue Ridge; on the south, it is bounded by Clarke County, Virginia. Its population has increased from 13,087 in 1820, to 15,005 in 1880, to 15,889 in 1910.

The county includes a farming area of the rich limestone valley and well watered. Practically the whole county is a farming and orchard area. It contains large deposits of valuable limestone and marl, and a number of quarries engaged in producing fluxing stone for the iron and steel industries, and these are described in a later Chapter. It has the only working iron mine in the State, and was in an earlier day a center of manufacture of natural cement at Shepherdstown.

Orchard Industry of Jefferson County. — A detailed orchard survey was made of Jefferson County in 1914 by R. R. Jeffries for the State Agricultural Experiment Station (Bulletin 147). The following facts are taken from this report. In 1876, there were 40 acres of orchards in the county; and in 1913, 4,385 acres, with 195,524 apple trees, so that 3.6 per cent. of the farm land of the county is planted in apple orchards.

The orchards range in size up to 320 acres. 34.8 per cent. of the trees were planted in the years 1900-1905. 76 per cent., or over three-fourths, of the trees were planted in the past 13 years. The largest yield and income is obtained from trees between 19 and 22 years of age, where the average is 83.8 barrels or an income of $207.26 per acre. Trees 7 to 10 years of age yield an average of 15.8 barrels per acre. The Ben Davis and York Imperial varieties are most common, each being over double the number of trees of any other variety.

The average Jefferson County orchard over ten years of age produced 45.4 barrels of apples, with gross income of

$95.53 per acre, or a net income of about $34.05. 51 per cent. of the orchards are producing more than 60 barrels per acre. Most of the orchards are planted 30 x 30 feet apart, with 48 trees to the acre.

The following **towns and settlements** are located in the county:

Bakerton.	Harpers Ferry	Millvale.
Bardane.	Kabletown.	Rippon.
Bolivar.	Kearneysville.	Summit Point.
Charlestown.	Middleway.	Shenandoah Junction.
Duffields.	Engle.	Shepherdstown.
Halltown.	Leetown.	

Of these towns the following are located at the quarries: Bakerton, Engle, Kearneysville, and Millville. **Leetown** was the home of General Charles Lee, and General Gates lived near Duffields. The three largest towns are, Charlestown, Harpers Ferry, and Shepherdstown.

Charlestown.

Charlestown is the county seat and was established by Act of the Virginia Assembly in October, 1786, as follows:

"Be it enacted by the General Assembly that 80 acres of land, the property of Charles Washington, lying in the county of Berkeley, be laid out in such manner as he may judge best, into lots of one-half acre each, with convenient streets, which shall be, and is hereby established a town, by the name of Charlestown."

Charles Washington was a brother of George Washington. In 1860, the town had a population of 1,376; in 1900, 2,392; in 1910, 2,662. As early as 1797, it was made the location of the Charlestown Academy, and at the present time is the location of Powhatan College. It is a town of homes and has good stores, hotels, and a few manufacturing plants.

Harpers Ferry.

Harpers Ferry is located at the junction of the Shenandoah and Potomac Rivers and was first settled by Robert Harper not long after the settlement at Shepherdstown. The place was first called Shenandoah Falls. By Act of Congress in 1794, the Government Arsenal was located here and the gun factory erected in 1799. It was in operation until destroyed during the Civil War.

Kercheval writing in 1836 gives the following description of the Arsenal at that time (p. 371):

> "This is the location of the U. S. armory, and in the several shops are generally employed about 300 first rate mechanics, engaged in the manufacture of arms for the purpose of War. There are annually made about 6000 to 7000 muskets, 2000 to 3000 rifles, besides an immense number of swords, pistols, and other side arms. The Government employs at this establishment a superintendent general, a paymaster, and a number of clerks. The quantity of iron, steel, brass, and other materials annually wrought up, is immense. A vast number of strangers annually visit this place to gratify their curiosity in seeing and inspecting the public works and great mechanical operations, so extensively carried on. The machinery of the musket factory is wrought by the waters of the Potomac, and that of the rifle factory by the waters of the Shenandoah.
>
> "This site for the public works, it is said, was first marked out or recommended by the immortal Washington, and is certainly evidence of his superior skill and judgment in all military matters."

The bridge across the river replacing the old ferry was chartered May 22, 1836, and subscription books opened on March 26, 1838. It is mentioned by Howe as in use in 1845, and as 800 feet in length. The population at the present time is about 800.

The scenery at Harpers Ferry is probably as grand and picturesque as at any place in the State, and was described by Thomas Jefferson in language which is regarded as a literary classic. His book entitled "Notes on Virginia", published in 1788, passed through several editions. The following description of the scenery at Harpers Ferry is taken from the edition of 1801 (p. 27):

> "The passage of the Potomac through the Blue Ridge is, perhaps, one of the most stupendous scenes in nature. You stand on a very high point of land; on your right comes up the Shenandoah, having ranged along the foot of a mountain a hundred miles to seek a vent. On your left approaches the Potomac, in quest of a passage also; in the moment of their junction they rush together against the mountain, rend it asunder, and pass off to the sea. The first glance of this scene hurries our senses into the opinion that this earth has been created in time; that the mountains were formed first; that the rivers began to flow afterwards; that in this place particularly they have been dammed up by the Blue Ridge of mountains, and have formed

an ocean which filled the whole valley; that, continuing to rise, they have at length broken over at this spot, and have torn the mountain down from its summit to its base.

"The piles of rock on each hand, particularly on the Shenandoah, the evident marks of their disrupture and avulsion from their beds by the most powerful agents of nature, corroborate the impression. But the distant finishing which nature has given to the picture, is of a very different character; it is a true contrast to the foreground; it is as placid and delightful, as that is wild and tremendous; for the mountains being cloven asunder, she presents to your eye, through the clefts, a small catch of smooth blue horizon, at an infinite distance in the plain country, inviting you, as it were, from the riot and tumult warring around, to pass through the breach and participate of the calm below. Here the eye ultimately composes itself; and that way, too, the road happens actually to lead. You cross the Potomac above the junction, pass along its side through the base of the mountain for three miles, its terrible precipices hanging in fragments over you, and within about twenty miles reach Fredericktown, and the fine country around that. The scene is worth a voyage across the Atlantic; yet here, as in the neighborhood of the Natural Bridge, are people who have passed their lives within half a dozen miles, and have never been to survey these monuments of a war between rivers and mountains which must have shaken the earth itself to its centre."

While the explanation of Jefferson can hardly be accepted now for the origin of this gorge with more knowledge available for the study of rivers, the description of this beauty spot in nature could hardly at this day be equalled. It deserves to remain a classic bit of description in poetic prose. Jefferson delighted in this scenic area and his favorite viewpoint was from a high rock on the mountain back of the town of Harpers Ferry which commanded a superb view of the rivers and the gorge. He doubtless was sitting on this rock when he composed the above description of the gorge. This rock is the object point of tourists of the region at the present and is known as "Jefferson's Rock".

Howe visited the rock in 1845 and thus describes it at that time (p. 335):

"The top of the rock is flat, 12 feet square, its base does not exceed 5 feet in width, and rests on top of a larger rock and its height is about five feet. The whole mass is so balanced that the application of a small force will cause it to vibrate considerably. On this rock once reposed another rock on which Mr. Jefferson during a visit to this place inscribed his name. In the extraordinary political excitement of 1798-9 between the Federal and Democratic parties, a Captain Henry who was stationed here with some United States troops, at the head of a band of his men, hurled off the apex of this rock."

One of the curiosities of the region is an outline of a face on the cliffs of the Maryland side as seen from Harpers Ferry. It bears a striking resemblance to the pictures of Washington and is pointed out to tourists by the guides. Howe in 1845 comments on this face on the cliffs as follows:

"There is said to be a wonderful likeness of Washington in the stupendous rocks which overhang the Potomac. The nose, lips, and chin are admirably formed and bear the semblance of studied art. The forehead is obscure; yet there is sufficient to give the mind a just idea of the noble form and dignified carriage, with its mildness of feature, which the original possessed so pre-eminently as to inspire all men with a profound reverence towards this august personage."

Shepherdstown.

Shepherdstown, under the name of Mecklenburg, was established by legislative Act in November, 1762, laying off 50 acres of land owned by Captain Thomas Shepherd, on the Potomac River, into streets and lots. Its population in 1850 was 1,561; and in 1910, 1,070. It was the home of Rumsey, the inventor of the steamboat, and was the location of one of the early cement mills in the country described in a later Chapter. The town is reached by the Norfolk and Western Railroad and there is here a wagon bridge over the Potomac. Shepherdstown was the county seat of Jefferson County from 1865 to 1871, and was in consideration at one time as a location for the National Capital.

At this place was located one of the oldest academies in Virginia. It was in existence in 1787 and was probably established before 1776. In the fall of 1871, the old court-house was leased for educational purposes and Shepherd College, a classical and scientific institute, was opened. On February 27, 1872, the Legislature of West Virginia passed an Act establishing a "Branch of the State Normal School at Shepherd College for the instruction and practice of teachers of free schools in the science of education and the art of teaching." The school was opened November 21, 1872, and the complete work was established in September, 1873. In 1909 the building of Shepherd College was leased by the State for a period of 25 years. A second building was erected in 1889 by the citizens of the town and is used as a model school and for an armory. A new building was erected in 1904 on grounds purchased by the State and is used for class work, library, society halls, and auditorium seating 700. The school has an enrollment of about 300.

STATISTICS.

The following statistics of the three counties are taken from the U. S. Census reports of 1910:

The **population** by districts in the counties is as follows:

Morgan County:		Berkeley County:		Jefferson County:	
Allen	1,148	Arden	1,844	Charlestown	5,444
Bath	2,280	Falling Waters	1.266	Harpers Ferry	3,176
Cacapon	2,312	Gerrardstown	2,433	Kabletown	2,132
Rock Gap	773	Hedgesville	2 596	Middleway	2,105
Sleepy Creek	713	Martinsburg	10,698	Shepherdstown	3,032
Timber Ridge	622	Mill Creek	1,571	Total	15,889
Total	7,848	Opequon	1,591		
		Total	21,999		

If the above figures of population are compared with the area of the counties in square miles, it will be seen that the density of population is light,—

Morgan County	34 people to the square mile.
Berkeley County	68 people to the square mile.
Jefferson County	75 people to the square mile.

The following **agricultural statistics** are taken from the U. S. Census for 1910:

Total Value of Crops, 1910.

Morgan County	$ 418,975
Berkeley County	1,231,255
Jefferson County	1,265,266

Morgan County has 149,120 acres, of which 107,659 acres are in farms, or 72.2 per cent. Of this farm land, 44.3 per cent. is in cultivation. There are 866 farms with an average area each of 124.3 acres. The average value per acre is $10.31. The value of farm property is $1,959,375, and the value of the farm lands is $1,110,357.

Berkeley County has 208,000 acres of land, of which 159,216 are in farms, or 76.5 per cent. Of this farm land, 73.4 per cent. is improved. There are 1,288 farms and average number of acres to a farm is 123.6. The average value of the farm land per acre is $29.38 (the State average is $20.65). The value of farm property is $7,523,456 and of the farm lands is $4,676,980.

Jefferson County has 135,040 acres of land, of which 120,786 are in farms, or 89.4 per cent., and 86.7 per cent. of this land is improved. There are 836 farms and average acreage per farm is 144.5, and average value per acre is $53.55. The value of farm property is $9,946,933, and the value of farm lands is $6,468,679.

The following statistics show the **changes in population** of the three counties as given in the U. S. Census Reports:

	1790	1800	1810	1820	1830	1840	1850
Morgan	......	......	......	2,500	2,694	4,253	3,557
Berkeley	19,713	22,006	11,479	11,211	10,518	19,972	11,771
Jefferson	......	......	11,851	13,087	12,927	14,082	15,357

	1860	1870	1880	1890	1900	1910
Morgan	3,732	4,315	5,777	6,744	7,292	7,848
Berkeley	12,525	14,900	17,380	18,702	19,469	21,999
Jefferson	14,535	13,219	15,005	15,553	15,935	15,889

TIMBER RESOURCES AND THE LUMBER INDUSTRY.

Mr. A. B. Brooks has described very fully the timber resources and the lumber industry of the State in Volume V of the West Virginia Geological Survey Reports. The portions of this report that apply to the eastern Panhandle area are here reproduced from that volume, and should be of special interest and value to the citizens of this section and to all who may wish to know more about this eastern section of the State. The following paragraphs are taken from Professor Brooks' report:

"MORGAN COUNTY.

"The kinds and abundance of timber were usually mentioned in early days, to indicate the value of the soil; but it must be concluded that at least some value was placed by Washington on the timber itself, for he instructed 'The Tenant not to remove any of the Walnut timber from the Land; or to split it into rails; as I should reserve that for my own use.—'

"From his intimate acquaintance with the forests of the county for the past forty years Dr. William H. McCullough, of Sleepy Creek, is able to give the following list of trees with approximate percentages showing their former relative abundance:

"Chestnut Oak	20 per cent.
White Oak	20 per cent.
Pines (including White, Pitch, Scrub and Yellow Pine)	10 per cent.
Black Oak, Red Oak	20 per cent.
Chestnut	20 per cent.
Others (including Sugar Maple, Red Maple, Locust, Hickory, White Ash, Cherry, Hemlock, Basswood, Black Gum, Black Walnut, Sycamore)	10 per cent.

"The Lumber Industry and Timber Destruction.

"The rich bottom and cove land of the county was sought after and occupied at an early date and much of the best timber destroyed before it had a merchantable value.

"It can not now be ascertained when the first water-power saw mills operated nor what were the names of their owners. It is stated that these primitive mills were once numerous along the larger tributaries of the Potomac and that large amounts of excellent lumber were manufactured to supply local demands. The first steam saw mill—at least in the northeastern part of the county—is said to have been put in operation near Cherry Run by Louis Shipley in the year 1870. Soon after this date, it is certain, mills of this kind became numerous and have so remained to the present. At first, when prices were low, only the choicest lumber was manufactured and sold; later, when prices became high, only the more inferior timber remained. For this reason, therefore, the lumber industry has often proved unprofitable both to the original owner and to the manufacturer.

"Waste has been everywhere in evidence. Bark from the chestnut oak timber—once so abundant on all the dry mountain ridges—was stripped off for local tanneries at Berkeley Springs, Pawpaw and other points, and the trunks left on the ground to decay; wasteful methods of lumber manufacture have been employed; a great number of young trees have been cut—especially during the last 15 years—for mine props, cross-ties, poles and pulp wood; and forest fires have prevailed in the wooded mountains during dry weather for more than a century.

"Present Forest Conditions.

"There are no virgin forests of any consequence now remaining in the county. The cut-over forests lie on the 3 principal mountains and comprise an area of about 25,000 acres. The timber on the cut-over areas is not good. The prevailing species are white oak, black oak and chestnut oak, with a scattered growth of other more or less stunted hardwoods, and with a few white, yellow and scrub pines.

"The large number of healthy young locusts growing now in the county will be a valuable asset to all owners of woodland provided the trees are not seriously molested for a period of 20 years.

"The wooded mountains—although producing but little timber and of an inferior grade—are, nevertheless, indispensable factors in keeping up the water flow of the many streams throughout the whole region. The forest cover, for the purpose mentioned above, should be maintained and protected at all hazards. The water power capable of development is very great. An electric plant located at the Horseshoe Bend of the Great Cacapon River is now supplying light to the towns of Berkeley Springs, Hancock and Great Cacapon, and power to a number of sand plants near the town of Berkeley Springs.

"The county is well adapted to fruit growing and considerable of the wooded hill land, almost worthless for the growing of other crops, is being profitably utilized for the culture of peaches.

"Outside of the cut-over timber lands the farmers in the valleys have from 25 to 40 per cent. of their farms in timber."

"BERKELEY COUNTY.

"Original Forest Conditions.

"There is little authority for making a definite statement in regard to the original forests of the county, for original conditions in most places have long ago passed away. This is particularly the case in the rich agricultural districts where the best of the timber must have grown. On some of the mountain ridges in the west, it is true, there are boundaries of woodland that have not been so greatly disturbed; but the timber on these often consists of such species as chestnut oak, bear oak, pitch pine and scrub pine, and does not fairly represent the original forests in other sections. It can be gathered from the character of the small and somewhat isolated woodlots of the eastern sections, and from the records left by various writers on the resources of West Virginia, that there was once an enormous growth of poplars, hickories and other hardwoods in the fertile valley lands. Yellow pine is said to have been common on Back Mountain and vicinity. Pitch pine and scrub pine, as well as chestnut oak and some other varieties, grew abundantly on thin dry land.

"The Lumber Industry.

"Hon. C. J. Faulkner, writing of the industries in Berkeley County in 1810, gives the following information: 'There are in this county upwards of 50 grist mills or merchants mills, as many saw mills, several fulling mills, an oil mill and a paper mill.'

"It is probable that within 25 years from the above date the number of saw mills in operation was much smaller. From Joseph Martin's list of the wood-working industries of 1835 we learn that there were '7 wagon makers, 1 chair maker and 3 tanners' at that time, but no mention is made of even a single saw mill.

"After the days when the old, upright saw mills had ceased to flourish in the county, small portable mills were brought in and have been moved from place to place for 50 years, sawing out 'sets' wherever a few score logs could be brought together. Four or 5 mills still run irregularly.

"Much of the good white oak was cut for ship timber. The chestnut oak has been peeled for tan-bark and the trunks used for railroad ties.

"A water-power mill at Tuscarora was built in 1809; and a water-power box factory has been operated on the Opequon for about 100 years.

"The Auburn Wagon Company, of Martinsburg, uses about 2 million feet annually of oak, ash, hickory, pine, gum and poplar in the manufacture of vehicles of various kinds.

"Present Forest Conditions.

"Mr. Alexander Clohan, of Martinsburg, gives the following information regarding the present conditions in Berkeley County:

" 'The best tract of timber east of North Mountain contains about 27 acres and lies a short distance west of Tabler station on the Cumberland Valley Railroad. The woodlots belonging to the farmers throughout this section are fairly good but about half of the land owners have none at all.

" 'Following down the Opequon we find the pine hill lands lying between Berkeley and Jefferson. Most of the pine here is 'Bull' pine and scrub pine and is not valuable commercially except for boxes, etc.

" 'There is more timber and a much greater percentage of woodland from the middle of the county westward. The west side of North Mountain is covered with fairly good timber, consisting of hickory, pine, chestnut, chestnut oak, black oak and others. Lower down there are water maples, sycamores and others that usually grow with them. There is probably an area of about 1,000 acres in that section that has not been closely cut over. This is held in rather small tracts by different owners. There are about 10,000 acres of forest land on Back Mountain and on Sleepy Creek Mountain. The timber on this area is of little value except for staves and cross-ties.

" 'Gerrardstown and Hedgesville Districts are the roughest and most mountainous in the county. The other 5 districts are well improved, Arden and Opequon having perhaps 90 per cent. of cleared land.

" 'Pine comes up almost spontaneously on abandoned land on the west side of North Mountain, and on the east side locusts seem to predominate'."

"JEFFERSON COUNTY.

"Original Timber Conditions.

"The fertile limestone areas of the county once contained a superior stand of hardwoods. Of these the chief were probably white oak, red oak, hickory, poplar, ash, and black walnut. Others of the hill land were chestnut (on Blue Ridge), pitch pine, scrub pine, locust, chestnut oak and scarlet oak.

"No definite data can now be collected regarding original conditions as the forests have long since been cleared away or stripped of their virgin growth.

"The Lumber Industry

"Jefferson County has been settled for nearly 200 years. For more than 100 years, certainly, after the settlement of Shepherdstown (then Mecklenberg) in 1727, there could have been little or no commercial use made of the trees that were cut. When the Baltimore and Ohio Railroad reached Harpers Ferry in December, 1834, however, the timber of the county began to have some marketable value, especially as it was of good quality and easily accessible from this terminus. From 1834 to the present the county has furnished a large amount of timber. Many of the young trees standing when the forests were first cut over reached a large size within a hundred years and were cut as a second crop.

"Mr. J. Garland Hurst, of Harpers Ferry, says that water-power saw mills were once common along the streams and sawed not only for domestic use but for commercial purposes as well. There is still one water-power saw mill in running order at Halltown on Flowing Run. Steam saw mills have operated irregularly in the county for many years. Joseph Martin, an early writer on the resources of Virginia, lists 2 saw mills for Jefferson County in 1835. One of these, located at Harpers Ferry, he asserts was 'one of the most valuable in the United States.'

"There are 4 or 5 portable saw mills now in the county.

"Present Forest Conditions.

"At least 75 per cent. of the whole county has been cleared. There are some small, pastured woodlots connected with the farms in the improved sections. The West Virginia side of the Blue Ridge Mountains is largely covered with a growth of inferior hardwoods. There are areas of considerable extent also overgrown with scrub oaks and pires near the Berkeley County Line."

PLATE III.—Topography of the Shale Hills west of Cedar Grove Schoolhouse.

CHAPTER II.

PHYSIOGRAPHY OF THE EASTERN PANHANDLE COUNTIES.

Topography refers to the configuration of the surface of the land, the hills, mountains, streams, and valleys. Physiography is the study of the topography or surface features of the land, in its characters, origin, growth, and final destiny. The systematic study of this subject is mainly American. Lesley in Pennsylvania as early as 1840 was an enthusiastic student of the subject and has given to the world important contributions to the science. The early students of topography saw the relation of earth structure to water action resulting in the planing down of the land surface and its sculpture, but they believed the work was due to an instantaneous or cataclysmic force, and not a gradual continuous operation. As stated then by Lesley, who afterward abandoned this view, "the present waters are the powerless modern representatives of those ancient floods which did the work". Topography was thus the result of extinct processes.

The modern conception of the work of land sculpture began with the illustrious work of Powell and others in the geological survey of the West about 1870. The wonderful erosion effects in that western country brought new land problems and new solutions to old problems, and modern physiographical science resulted. They found in those western plains and plateaus that topography was clearly the direct result of erosion. It was erosion that carved the hills and mountains and deep canyons and valleys often in most picturesque patterns. Erosion not content with patterns produced, changed these into still other forms, and it is ever at work in this process of change. The engraving tools of frost, heat, and cold, wind, rain, running water, are making great waste of land material which is started on its almost ceaseless march, short or long, to the sea, the final resting place for such materials. The sea floor may be raised and the work started over, as has happened repeatedly.

In order to understand the results of all this work of atmospheric and aqueous agencies on the land area, let imagination picture the growth of a typical land area. The sediments accumulating below the waters of the sea become cemented together and consolidated into rock masses which by earth movements are raised into dry land, a smooth upland plain or plateau with its minor depressions and irregularities. The rains descend upon this land and the water gathers in the depressions and flows off in small rivulets. These small streams flow together and form larger ones and pursue their paths seaward. With increase in volume the creeks become rivers in deeper and deeper channels. The larger streams follow nearly parallel courses separated by low divides with lakes in the depressions. With the cutting action of the silt laden waters, the channels are cut deeper, the little tributaries are enlarged, cutting backward into the divides until the land area is covered with a branching net-work of streams like the branches and twigs on the trunk of a tree, a **dendritic** arrangement. Side by side with the waste of the land through erosion by water, the atmospheric agencies are at work widening the upper portions of the valleys which thereby lose their trench-like character and approach V-shaped valleys.

As these young streams cut their channels downward, obstructions may be met, a mass of hard rock or other material, and the run or creek bends around it, or the inequality of the original surface may deflect its course, so that the path seaward is not the straight and narrow one, but a more or less winding course. The head of the stream and every tributary are cutting backward in a course more or less irregular, so that the final course may be very different from its original. The stream may also wind on its flood plain, resulting in a meandering river or creek. As this erosive work goes on day and night, year after year, century upon century, through the eons of time, the streams on the two sides of the divide approach each other, finally cutting away the divide into a series of hills which are further attacked by the tireless energy of water and air, until they also are removed wholly or in part. There remains a smooth plain no longer upland but lowland near the level of the sea, and the land is said to be at **base-level**, and the cycle is completed from sea-plain through upland-plain to coastal-plain. This new plain is not the level area it was in the beginning of its history, for here and there are the low hills left between the streams, but it is **almost** a plain, and so has been named a **peneplain (pene**—almost). Earth's forces may again raise the low peneplain to an upland, and the work of erosion begins a second time, following the same line of development. There will remain characters which usually identify the old plain, and as a result of the study in the Appalachian area, three such plains are clearly identified with a fourth in many parts of the area. These four plains are discussed in a later portion of the present Chapter.

TOPOGRAPHICAL DIVISIONS.

The studies referred to as taking place in the far West established many fundamental principles of physiography which later found an application in the eastern part of the United States. As a result of the work in this eastern section by McGee, Willis, Davis, Hayes, Campbell, and others, we now have an interesting geological history of the development of the topography of the eastern part of the continent. New York, Pennsylvania, New Jersey, Maryland, West Virginia, Virginia, and the States to the south, may be divided into three general topographical divisions—Coastal Plain, Piedmont Plateau, and Appalachian Area.

The COASTAL PLAIN represents the fringe of land from Maine to Florida and around the Gulf Coast which is composed of horizontal beds of usually unconsolidated sediments of late geological age. In width it extends from the Atlantic coastal shelf west to the crystalline rock plateau. Its history has been one of subsidence and elevation probably oft repeated. Its contours are low, its valleys broad, often forming estuaries near the mouths of the streams.

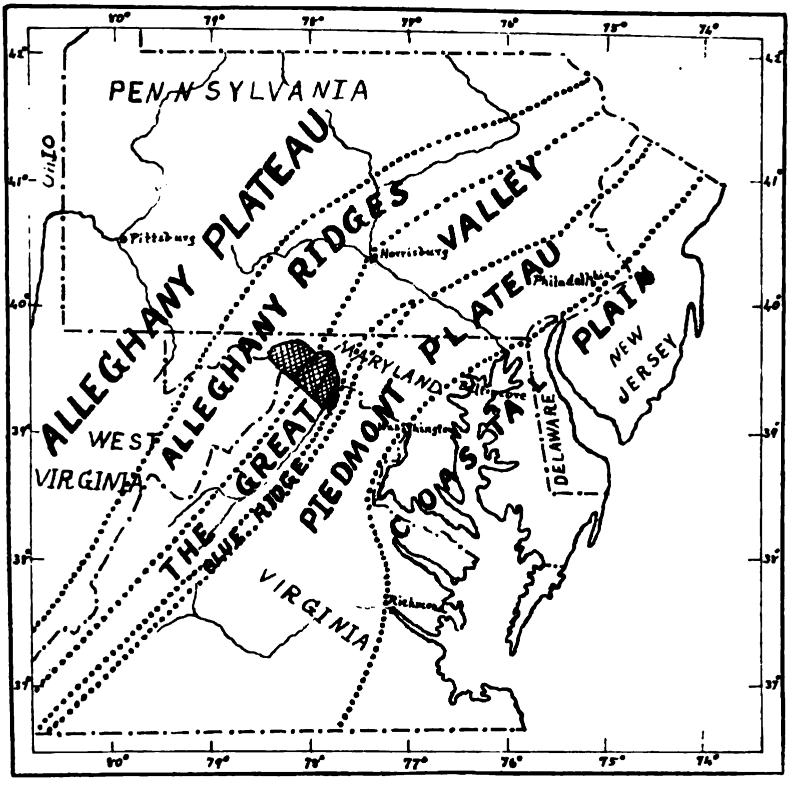

Figure 4. Map showing the Topographical Divisions of the Eastern United States.

The PIEDMONT PLATEAU lies along the eastern foot of the Appalachian Mountain ranges. It extends west to the Blue Ridge Mountains and east to the Coastal Plain. This eastern line is often called the "Fall Line" as the larger streams are navigable below this line, while above they are marked by waterfalls or rapids. This location represented in the early history of the country the upper limit of navigation and the lower limit of water power, a combination of natural advantages which determined settlements; and along this line, as a result of these early settlements under such favorable conditions for development and growth, the present large eastern cities are located, New York, Philadelphia, Baltimore, Washington, Richmond, etc. This area is an upland plateau cut into by valleys, and with higher hills mostly even capped. The eastern portion is made up of highly folded and inclined crystalline rocks, while at the west are the folded and faulted sedimentary rocks. The plateau slopes both ways from a central axis of Parrs Ridge which reaches a height of 900 feet and dips eastward to 400 feet, and westward to 600 feet.

This upland plateau appears to extend westward on the even crests of the mountains in the next province, and as stated by Abbe in his discussion of the Physiography of Maryland[1], "the Piedmont plateau upland is generally regarded as being but the seaward remnant of a broad, gently rolling surface, which once extended westward beyond the Alleghany Front, northward along the Appalachians into New York and New England, and southward across the Cumberland Plateau of Tennessee to an unknown distance. This broad plain was cut indifferently across crystalline and folded sedimentary strata and was produced during the final stages of that long-continued denudation which has resulted in exposing the roots of the Piedmont Mountain chain." This plateau and the even crests of the mountains to the west represent the old Schooley Peneplain which is described in another section of the present Chapter.

The APPALACHIAN AREA extends from the eastern foot of the Blue Ridge or the Piedmont Plateau westward to the Ohio Valley, and south to Alabama, and north into New York. Its rocks are nearly all of the sedimentary type laid down near the eastern shore of the Paleozoic Interior Sea, the sediments being derived from the waste of the Land mass to the east. The deposition was accompanied by subsidence so that the thickness of the present rocks is very great. By later movements the rocks were raised into land areas and also compressed into folds, and then the surface was modified by erosion and crustal movements.

Abbe in his studies in Maryland (loc. cit., p. 153) divided the Appalachian Area into four subdivisions based on the general type of topography which differs in the four districts.

[1]Maryland Weather Service, Vol. I, p. 120; 1899.

The same subdivisions apply to West Virginia, and they are named from east to west,—The Blue Ridge, The Great Valley, The Alleghany Ridges, and The Alleghany Plateau, all of which, except the last one, are included in the area of the eastern Panhandle Counties. The entire area of these counties is included wholly in these groups of the Appalachian Area; the Coastal Plain and Piedmont Plateau being east of the State of West Virginia.

The **Blue Ridge subdivision** includes the Blue Ridge, the Catoctin Mountain, and the district between the two mountains. The western slope of the Blue Ridge is found near Harpers Ferry. This mountain extends from South Mountain in Pennsylvania south into Virginia, being broken by the Gettysburg Gap and by the Potomac Gorge at Harpers Ferry. Its height at Harpers Ferry is 1200 feet, reaching 1600 farther south on the line of Jefferson County. The Valley of the Shenandoah at the foot of the mountain is 300 to 400 feet above sea-level and the distance from the mountain crest varies from one to two miles. The Potomac has cut its deep gorge through the mountains at Harpers Ferry between the two high points called Maryland and Loudoun Heights, one of the most scenic points in the State.

The **Great Valley subdivision** extends from the Blue Ridge west to North Mountain. It is a broad, fertile, limestone and shale valley, but mostly limestone. The surface is rolling and marked by low hills and shale ridges. The average elevation of the valley in West Virginia is 400 to 450 feet above the sea, rising from about 400 feet near the Potomac River to 600 feet near the mountains. The streams are mostly small with their valleys cut into the limestone and shale. It is one of the richest agricultural regions of the State.

The Valley is crossed by the Baltimore and Ohio Railroad and a study of its profile would indicate the general character across the valley, but in the mountain area to the west, the road follows the river and would there indicate only the character of that narrow valley. It must, however, be borne in mind that the railroad grade is modified to some extent by cuts and fills, but these are usually through minor inequalities. The following table shows the levels above tide of the

Baltimore and Ohio Railroad across the Valley to North Mountain and thence west to Pawpaw. The railroad follows the Potomac River from Pawpaw to beyond Cherry Run, and then cuts across the Valley to Martinsburg, reaching the Potomac again at Harpers Ferry:

	Feet A. T.	Miles.
Harpers Ferry	286.5	0.0
Engles	379.6	3.7
Shenandoah Junction	518.7	7.7
Kearneysville	552.0	11.2
Van Clevesville	475.2	14.0
Martinsburg	427.7	18.6
North Mountain	540.0	26.2
Cherry Run	401.7	32.3
Sleepy Creek	401.2	36.3
Hancock	420.3	41.7
Sir Johns Run	426.1	47.3
Great Cacapon	447.2	51.4
Magnolia	498.2	67.8
Pawpaw	529.8	72.7

The highest point on the grade is at the east near Kearneysville, 552 feet above tide, as compared with Pawpaw, 529.8 feet. The railroad goes down grade from Pawpaw to Cherry Run, with an average descent of three feet to the mile. From Cherry Run to Kearneysville, the average rise is seven feet to the mile, and it then falls to Harpers Ferry with an average of nearly twenty-four feet to the mile. The average fall from Pawpaw to Harpers Ferry would be 3.3 feet to the mile. Across the Great Valley from North Mountain to Harpers Ferry, the fall on this grade is 253.5 feet in a distance of 26.2 miles, or nearly ten feet to the mile.

The Cumberland Valley Railroad levels may be taken from Winchester to the Potomac as illustrative of the character of a railroad grade north and south through the Valley, as follows:

	Feet A. T.	Miles.
Winchester	716.8	0.0
Bunker Hill	556.1	12.5
Inwood	568.9	14.3
Darkesville	553.9	15.5
Tablers	553.0	17.6
Martinsburg	460.5	22.2
Berkeley	468.0	26.1
Bedington	383.0	28.1
Falling Waters	364.0	30.7
Old Bridge Potomac	382.0	33.8

The fall in grade from Bunker Hill to the Potomac is 174.1 feet in 21.3 miles, or 8.6 feet to the mile. The fall from Martinsburg to the river bridge is nearly 6.8 feet to the mile.

The Alleghany Ridges. — These ridges follow parallel northeast-southwest courses, and owe their origin largely to a protecting cap of resistant sandstone or conglomerate. On the higher ridges, this hard stratum is of Carboniferous age, but on the lower ridges, it is an Oriskany or a Chemung Sandstone. The top of North Mountain is the hard white Medina Sandstone. Between these ridges are stream valleys usually narrow. The ridges vary in height from 600 to 2300 feet on Cacapon Mountain. The upper valley levels and the ridge levels are remnants of old peneplains. The further description of the details of the Great Valley and the Alleghany Ridges topography in the eastern Panhandle area will be found in a later portion of this Chapter.

EVOLUTION OF THE NORTH AMERICAN CONTINENT.

In order more clearly to understand the geological history of the topographical development of the eastern Panhandle Counties, a brief resume will be given of the growth of the North American Continent from the earliest geological records to the present time. This history will only be summarized in this place, and the reader can find more detailed data on this interesting subject in various standard works on Historical Geology. The geological terms used in this discussion are explained in the next Chapter, and they represent divisions of the geological time scale.

A study of the igneous and sedimentary rocks of the geological column gives clue to the history of the growth of the continent, and shows how the land area has been built up era after era. The general outline of the North American continent was marked out in the earliest land areas of the early Archean time. The original Archean-Algonkian land areas are found in the large nuclear V-shaped mass of these rocks around Hudson Bay with a peninsula extending down into Wisconsin. Island ridges were located along the Atlantic border, and there was an elongated land area near the present site of the Appalachian Mountain range, a land mass which for descriptive purposes has been named, by Willis, Appalachia. Islands marked the Rocky Mountain site, and a large island marked the Ozark area in Missouri. These land masses became the theatre of great work of denudation, for from them must have come all the sediments that formed the later sedimentary rocks either directly from this original land or from later land masses composed of their sediments.

At the close of Cambrian time this land mass was increased by the Cambrian rocks, though in early Cambrian the land mass seemed to have been far greater than at the close of that period. Evidence seems to show that in early Cambrian time the whole interior of the continent was land probably not very high above sea-level. In later Cambrian time, the sea encroached on the land and there was a period of subsidence, resulting in a vast interior sea, a subsidence which continued into Ordovician time.

Near the close of Ordovician, elevation of the sea-floor took place and the limestones are succeeded by shales derived from mud sediments. At the close of the period there was a marked elevation of the land areas, connecting the Appalachia land with the northern enlarged V-mass thus closing the straits at the northeast, so that the interior sea was now only open to the south. A small anticline was formed in Ohio extending into Tennessee. This Cincinnati axis made a partial separation of the Interior sea, and the Ozark island was enlarged. The Green and Taconic Mountains probably date from this uplift, though modified by later elevation.

The upper Silurian period opened with shallow water in which conglomerate rocks were deposited (Oneida) evidence of shore-line conditions, and then sandstone (Medina) was formed on the eastern borders, followed by shales and limestones (Clinton) extending from New York west to Wisconsin, and then deeper seas of the Niagara. Later in the period there were salt lakes at the northeast (Salina). Near the close of the Silurian, the Missouri island was joined to the Wisconsin peninsula.

In the early Devonian the northeast straits were reopened by subsidence. In the east the thick sandstones of the Oriskany were laid down as shore deposits followed by deeper water (Corniferous) west into Iowa, then came the muddy waters of the Hamilton representing an eastward movement of the shore-line of the interior sea. Toward the close of the period, the sandy shales and sandstones of the Chemung and Catskill Formations were laid down. By the end of the Devonian, New England and Canada were dry land except for a few elongated bays in Massachusetts. The Cincinnati Axis was joined to the northern land mass and the Appalachian land mass was enlarged. The interior sea had now become two large bays extending across Pennsylvania, West Virginia, Ohio, Michigan, and neighboring States. The Rockies represented an area of subsidence.

In the early Carboniferous time, the interior sea bays were shallow and sandstones and conglomerates of the Pocono were deposited, mingled with remains of land plants. In the Rocky Mountain area, there was a heavy deposition of limestone and also in the southern part of the eastern sea (Greenbrier), but where the limestone was absent and even over it in places was formed a large red shale deposit of the Mauch Chunk. As the water became more shallow and swampy land areas emerged with oscillating changes of level, the rocks, coal, etc., of the Coal Measures were formed. At the close of the Carboniferous came the culmination of folding in the Appalachian Mountains, though the crustal movements resulting in this folding probably extended back for some time in the Paleozoic. At the close of the period, the continent had about the same relation of land and sea areas as at present except along the ocean borders and a few long troughs parallel to the Appalachians in which the Trias—Jura (Newark) rocks were later deposited.

During the Mesozoic era the Newark red sandstone was deposited in the troughs east of the Appalachians and in the sea estuaries. Along the borders of the continent and in the interior and in the West, Cretaceous sediments were deposited. There was a period of extensive denudation during this period and a transgression of the sea over the land in Upper Cretaceous over the Coastal Plain at the East and South up to southern Illinois, also over the West and the northwestern portion of the continent. At the close of the period elevation took place, the Rocky and other western mountains were formed. The Sierra range which was raised near the close of Trias—Jura time was further folded.

In the Tertiary period of the Cenozoic, the land additions were along the border of the continent and in interior lakes. There was marked volcanic activity in the Rockies and Yellowstone region. At the end of the Miocene division elevation of land to the south joined North and South America, the mountains of the west were further raised, and Florida was joined to the main land. It is possible there was further elevation in the eastern area. The Quaternary division of the Cenozoic was not a time of continental growth, but it was a time of great changes in topography through the action of erosion. This period includes the Glacial epoch when the northern portion of the continent was covered with a great ice sheet. This review brings the development down to the present era with its changes in topography taking place as in the past, but to our eyes the changes are very slow.

APPALACHIAN MOUNTAINS AND THEIR HISTORY.

From the preceding discussion of continental growth or evolution, it is seen that during the Paleozoic division of geological time, there was a great accumulation of sediments in the Appalachian area with a thickness that has been estimated at 40,000 feet. With the great accumulation of sediments in this sinking trough, and the contraction of the surface of the continent and globe by the gradual cooling of the earth's interior, stresses would be in force which by the weakening of the so-called crust along this sinking axis, finally culminated in yielding to the strain and elevation by lateral pressure with its resultant folding and fracture of the strata. This culmination took place at the close of the Carboniferous and the close of the Paleozoic division of geological time, resulting in the formation of the Appalachian Mountains which have been greatly modified later by erosion and further elevation. In fact, the present mountains of this range, as shown by Willis, are really mountains of vertical uplift and erosion, and not of folding by lateral pressure as so generally stated. The old Appalachians of folding have been worn away, but the base or roots of those mountains exist in the present erosion mountains, classic examples of folds in mountain strata.

PENEPLAINS IN THE APPALACHIAN AREA.

Schooley Peneplain.—The early portion of the Mesozoic era in the Triassic and Jurassic was marked by a period of great denudation, reducing the eastern border of the continent to a base-level. This long period of erosion reduced the Appalachian Mountains to a peneplain on which projected more resistant hills or portions of divides further removed from the main drainage streams. There was left a featureless, monotonous plain, with a few projecting hills and ridges, that extended from the Ohio Valley to the Atlantic coastal shelf, northward across Pennsylvania, New Jersey, and into New York; south to a limit undetermined.

This great plain was named by Davis the **Schooley Peneplain** from its remnant on Schooley's Mountain in New Jersey. This plain cuts across the Triassic rocks, but according to the work of the Maryland Geological Survey, it is partially overlain by Jurassic rocks on the Coastal Plain, which would indicate that the denudation took place after Carboniferous time, and probably during the lost interval indicated by the unconformity at the close of that period and during Triassic time.

According to Campbell[1], the conditions necessary for such a complete peneplain are long-continued stability of sea-level so that the relative position of land and sea shall remain unchanged for a period long enough to allow the agents of erosion to tend to complete their work and reduce the land surface to the base-level of erosion. The completeness of this Schooley Peneplain indicates a very long time interval under the above conditions. Campbell, from data available, regards this period of denudation as eight or ten times longer than any of the later base-level periods. The old topographic forms

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[1]Nat. Geog. Soc., Vol. VI, pp. 63-126; 1894.

were obliterated and a new order instituted. The softer beds by later erosion have been reduced below this Trias-Jura plain, but the harder sandstone caps of the now level top mountains and ridges represent the remnants of this old plain.

The evidence of the relation of the Trias and Jura sediments to this plain as noted above, would indicate that the date of uplift of this peneplain was later than the Trias and it probably took place in the early Jurassic time. The area was then raised to a height now impossible to determine, but some parts of this plain are to-day at least 3,000 feet above sea-level.

Weverton Peneplain.—The work of the Maryland geologists[2] has disclosed another peneplain well shown on the sandstone ridges near Weverton in that State, and so named the Weverton Peneplain. It ranges in elevation from 700 feet in Montgomery County, 850 feet in northern Carroll County, to 300 feet on the Coastal Plain. Its age was determined by them as late Jurassic or early Cretaceous.

Harrisburg Peneplain.—The elevation of the Schooley and Weverton Peneplains started the work of erosion anew and valleys were carved in the uplifted peneplain inaugurating a new cycle of denudation and a new evolution of topography during the early Tertiary and the preceding Cretaceous. The upland plain was again worn down to base-level, but not as complete as in the case of the Schooley Plain due to a shorter time interval. In the early Tertiary period, there was another time of elevation and this base-levelled plain was raised into an upland peneplain. From a well preserved remnant of this plain near Harrisburg, Pennsylvania, Campbell named this the Harrisburg Peneplain. Its remnants are now seen over a wide area and it was almost coextensive with the Schooley Plain.

Somerville Peneplain.—During late Tertiary time, the Harrisburg upland plain was reduced to still another base-level, still incomplete as compared with that of the Schooley, and it has been named by Davis from its well preserved remnant in the area of the Newark rocks near Somerville, New Jersey, the Somerville Peneplain. It is developed in the weaker rocks, especially on the Cambrian and Silurian Lime-

[2]Maryland Geol. Survey, Vol. VI, pp. 76, 87; 1906.

stones and Shales. The harder Oriskany and Chemung Sandstones were modified by this denudation but not to the extent of the softer rocks. This plain is readily identified through the Great Valley and west to Cumberland, and east to the Coastal Plain, where it can no longer be separated and probably there is united with the other levels. In the late Tertiary, elevation raised this peneplain into an upland, and the streams are now eroding this plain and the present order of change is inaugurated reducing the Somerville Plain toward another base-level.

ELEVATION OF THE PENEPLAINS.—The remnants of the Schooley Peneplain in Maryland now have an elevation above sea-level of 400 feet on the Coastal Plain, rising westward to 1700 feet on Catoctin Mountain and keeping this level to west of Hancock. The Weverton Peneplain rises from an elevation of 300 feet on the Coastal Plain westward to 750 feet on Catoctin Mountain and 1300 feet, west of Hancock. The Harrisburg Peneplain apparently merges with the others on the Coastal Plain and reaches 600 feet near Harpers Ferry, and 800 feet, west of Hancock. As traced by Campbell, the Harrisburg Peneplain has an altitude of 1200 feet near Pittston, Pennsylvania, on the east branch of the Susquehanna River, 1200 feet near Cumberland, and 500 feet near Harrisburg. He regards this plain as corresponding to the 1250-foot plain along the Monongahela River. The Somerville Peneplain is merged with the others on the Coastal Plain, rises to 500 feet at Harpers Ferry, 600 feet, west of Hancock, 400 feet near Harrisburg, and 800 feet at Cumberland.

These levels show a general westward rise of the different peneplains and also to the north and south nearer the headwaters of the streams where erosion did not reach as high a degree of maturity as in the lower courses. It is also seen from these levels that the interval between the Harrisburg and Somerville Plains at Harpers Ferry is 100 feet; west of Hancock, 200 feet; and at Cumberland, 400 feet. The interval between the Schooley and Harrisburg Peneplains is about 1100 feet, east of Harpers Ferry; 900 feet, west of Hancock, and about 1000 feet near Cumberland. The interval between the

Harrisburg and Weverton Peneplains east of Harpers Ferry is 150 feet and west of Hancock, 500 feet. The interval between the Weverton and Schooley Peneplains east of Harpers Ferry (Catoctin Mountain) is 950 feet, and west of Hancock it is 400 feet. These differences in level between plains, regarded as parallel at the time of their formation, show that their elevation was not uniform over the area, or that the uniformity was altered by later movements. The plains are therefore warped to a larger or smaller extent over the area, but they all agree in an eastward inclination. Campbell, who early in the study of these old plains called attention to their warped character, states that while the easterly slope of the Harrisburg Peneplain may in part be due to the gradient of the stream while the plain was being formed, yet 90 per cent. must have been due to subsequent warping.

PENEPLAINS IN EASTERN PANHANDLE AREA. —In the eastern Panhandle Counties of West Virginia, the remnants of these four peneplains are found in many places, the younger plains naturally being better preserved than the older.

Schooley Peneplain.—A portion of this old plain is probably represented by the level top of Spring Gap Mountain in western part of Morgan County near Pawpaw, with a level of 1800 to 1900 feet above sea. It appears on Purslane Mountain just south of Rockwell Run at an elevation of 1700 feet, also on Cacapon Mountain south of Prospect Rock at 1700, rising to 2100 feet further south. It is seen on Sleepy Creek Mountain at an elevation of 1700 feet and about the same level on Third Hill. It is 1600 feet on the Blue Ridge in southeastern corner of Jefferson County.

Weverton Peneplain.—This plain is not so well preserved in this area as in Maryland. It is probably represented in the wind gap at Whites Gap on Third Hill Mountain at an elevation of 1300 to 1380 feet, also on top of Short Mountain at an elevation of 1300 feet. The upper part of the Meadow Branch Valley, at level 1200 to 1300, may also represent this plain, and also the crest of North Mountain at 1200 to 1240 feet. A series of 700- to 750-foot hills east of the Shenandoah River are probably remnants of this plain.

Harrisburg Peneplain.—This peneplain is seen on the ridge east of Pawpaw, 900 to 940 feet, on the small level-top hill south of Hansrote at 900 to 920 feet; south of Doe Gully in two small hills 900 to 920 feet. It is found on the southern portion of Bare Ridge at 900 feet; southwest of Woodmont on the upland terrace at 900 feet. There is a fine remnant at the 900-foot level on Cacapon Mountain southwest of Sir Johns Run Station; again, south of Roundtop at 800 to 900 feet; also on Horse Ridge and on the ridge just east of Berkeley Springs at 800 feet, and at Riderville around 800 feet. This plain is apparently found on the slopes of Third Hill Mountain at 900-foot terraces, and on Ferrel Ridge at 800 feet, and along North Mountain at 700 feet at the northern hills and 800 feet, further south. It probably forms the Bolivar hilltop at Harpers Ferry, at 600 feet, and the 600-foot terrace along the side of Blue Ridge in the southeastern part of Jefferson County.

Somerville Peneplain.—This plain is seen on a number of hills at 800 feet to west of Doe Gully and southwest of Hansrote in western part of Morgan County. It is found at various places along the Potomac Valley, as on the hills west of Sleepy Creek, at 600 feet and also one mile east of that town. It is seen south of Big Run and also in a series of hills south of Cherry Run at 600 feet. North of Soho, the 500-foot ridge probably is this plain, and at south end of Ferrel Ridge, the level is 600 feet. It stands at 500-foot level on the hills in the bend of Back Creek, north of Hedgesville road. It is seen at several places south of Hedgesville at 600 feet and north of Nipetown at the same level. Around Martinsburg, it is marked by the 500-foot hills, and the same across the valley to Harpers Ferry and the Shenandoah River.

DEVELOPMENT OF STREAM VALLEYS.

The rivers on an uplifted sea plain or on a peneplain pass through a cycle of development similar to that of the land forms. By analogy, this cycle is compared with the life history

PLATE IV.—View from Sideling Hill in Morgan County across Bare Ridge.

of organisms passing from the period of infancy through adolescence, maturity, to old age and death.

In the earlier life of the stream as it cuts its way downward, the valley slope is steep. Erosion is rapid through the softer rocks while the more resistant layers withstand the cutting force and remain for a time as projecting layers over which the water pours in rapids or falls, and the river is in its period of infancy passing into the period of adolescence. The river is now eroding its channel deeper and deeper, and but little from side to side.

As the valley floor approaches more nearly the level of its outlet, the current becomes less swift, the projecting ledges of the falls are brought to the general grade of the stream. The river can not now cut its channel downward as rapidly as before and it increases the erosion laterally, widening the valley. Its load of sediment before carried outward in the swifter current is now dropped in large part, and fills the lower part of the channel, spreading out in flood-plains. Over these plains the river may take a meandering course, winding from side to side, cutting into one bank and filling on the other. The river now carries its maximum load of sediment and performs its greatest work of erosion, so it is said to be in the **maturity** of its life.

When the river valley is graded to a level with the sea, reaching its base-level, the current is sluggish or absent, the sediment falls, obstructing the channel, and the river is no longer able to do its work. It has reached the period of **old age**, and settles down to a period of quiescence.

While the lower portions of a great river may reach this period, its headwaters may still be pushing their way backward, cutting into the divides further and further. A single stream may thus be in various periods of the life cycle from source to mouth, a **complex** river made up of parts. The divides are deeply dissected, and by the more rapid cutting of larger or swifter streams on one side, may migrate toward the weaker streams. If this action goes far enough, the divide finally may be cut through in places, tapping the headwaters of the stream on the opposite side, which may flow through the break in the divide and the waters pass seaward by the way of the faster working stream. The remnants of the old streams still pursuing their former paths are spoken of as **beheaded streams.**

On the uplifted sea plains, the water falling on the land will flow off toward the sea, following a channel worn into the rocks along a natural declivity, or an inequality in the surface. or cut into softer portions of the strata. Such streams following an original course determined by the surface structure have been named by Davis **Consequent streams.** An example of such a stream in the area under discussion would be the Potomac River, though it has undergone many changes in its later history. The consequent streams are fed by branches and these by subbranches and so on until in the mature river system there is a network of streams reaching all parts of the area. The stream and its branches spread out like the branches of a tree and the arrangement is called dendritic or tree-like, or trellis-like.

Subsequent streams are those developed in the mature period of the stream as branches not represented in the youth of the river. Such streams in this area as Cacapon River, Sleepy Creek, Back Creek, etc., are subsequent streams. When a peneplain is raised to an upland, the river and stream activity are increased and enter upon a new cycle of erosion, and they are now known as **Revived streams.** In some cases there may be a surface covering of materials over the older rocks by deposition of new sediments during depression of the area, by glacial material, or other causes; and the river carves its channel on the overlying strata, then cutting into the lower rocks preserves its first course even though it is out of accord with the structure of its deeper channel, cutting across bedding-planes, or on hard rocks when softer are easier to follow. Such streams are said to be **superimposed.**

Antecedent rivers are defined by Davis as those "that during and for a time after disturbance of their drainage area, maintain the courses they had taken before the disturbance." The Potomac at Harpers Ferry has cut its gorge through the Blue Ridge while the elevation of the area was in progress, and after the elevation was over, it maintained the course it had before the uplift, and is at that place an antecedent river. The

Shenandoah River, on the other hand, was apparently unable to cut down its channel at Snickers Gap as fast as the elevation took place and it was deflected northward to the Potomac.

In the eastern Panhandle area, the main drainage stream is the Potomac River, and its main tributary streams cut back to the southward in nearly parallel valleys with a general northeast-southwest trend. These tributary streams are fed by lateral ones mostly short and having still smaller branches. The drainage pattern is dendritic or tree-like, but somewhat a-symmetrical, as the branches are better developed on one side than on the other. The courses of these streams are direct though somewhat winding in the larger tributaries. A detailed discussion of the streams of the eastern Panhandle area will now be given.

THE EASTERN PANHANDLE STREAMS.

POTOMAC RIVER.—The Potomac River, the main drainage feature of the region, forms the boundary line between Maryland and West Virginia along the northern line of the three counties of the Panhandle area. A straight east and west line, from the river where it first strikes Morgan County in the southwestern corner of that county, would reach the same river at about the mouth of the Opequon, which is thirteen miles north of a parallel line from the river at Harpers Ferry. In the center of the area, the river reaches a point twelve and a half miles north of this first east and west line. The river thus makes a large swing to the north and then to the south, and follows a very meandering course on its northern and southern swings, while its easterly course is marked by only a few meanders and these meanders are mainly in northern Berkeley County.

The length of the channel around these three counties is 132 miles, with a fall from 520 feet in altitude to 260 feet at Harpers Ferry, or two feet to the mile. From the southwestern corner of Morgan County, the river follows a strongly meandering course northeast 28 miles to near Lineburg, and the air-line distance is eleven miles. Two of the river bends extend three miles to the west at Magnolia and Doe Gully.

The bends are very symmetrical and deeply trenched in the valley. The fall of the river in this section is low, averaging two and a half feet to the mile, though on the bend at Magnolia for a distance of five miles, the fall is four feet to the mile From Lineburg to Sir Johns Run, the fall of the river is six feet to the mile and the channel is not winding. From Lineburg, the river flows east to Cacapon Mountain in a transverse valley, five miles of straight channel with a fall of only 1.7 feet to the mile. It then turns northeast nine miles to Hancock, curving in a small meander around the hard sandstone ridge near Roundtop. This meander is nearly a half mile wider than its former channel. From Hancock the river flows southeast in a nearly straight channel twelve and a half miles to within a mile of the mouth of Back Creek. The fall of the river from Sir Johns Run to this point is 1.3 feet to the mile, but near the mouth of Back Creek the fall increases to 4.4 feet to the mile, then drops to 2.3 feet to a point one and half miles beyond dam No. 5. Near Back Creek the river turns east for three miles to the double ox-bow at Little Georgetown. From this town to dam No. 5 is two miles by air-line and six and a half miles by the river and this portion of the channel has a fall of 2.3 feet to the mile. From dam No. 5, the river runs east with a north bend along the cliffs at Indian Church, seven miles to Williamsport, where it turns due south for two and a half miles, then bends west three miles to Falling Waters, thence southeast and east to the big bend at Whitings Neck, then east by dam No. 4 which is ten miles below Falling Waters. The fall from one and a half miles below dam No. 5 to Whitings Neck, sixteen and a half miles, is 1.1 feet to the mile, but increases in the next four miles to dam No. 4 to 4.4 feet to the mile. From dam No. 4, the river follows a very winding channel 12 miles long to Shepherdstown with a fall of 1.66 feet to the mile. The air-line distance is four miles. From Shepherdstown, the river flows east two and three-fourths miles, then south to Harpers Ferry. The distance by river is 13 miles, with a total fall of 30 feet, or 2.3 feet to the mile.

The Potomac River Valley is cut through the Devonian Shales from the southwestern corner of Morgan County along most of the course to beyond Back Creek, except where it is cut through the mountain ranges. At Lineburg, it cuts through a gap in Carboniferous Sandstone in Sideling Hill. The gap in Tonoloway Ridge is cut through the Oriskany Sandstone and the underlying limestones. It then cuts through Silurian Shales to the Warm Spring Ridge, where it again cuts through the Oriskany Sandstone and the limestones below. It then cuts across the Devonian shales and sandstones to beyond Back Creek and then across the valley limestones and shales of Silurian, Ordovician and Cambrian.

Its valley is at first parallel to the mountains and is there a consequent stream, then it cuts across the strata in a transverse valley, then in a parallel valley or longitudinal to Hancock, then in a transverse valley again to Williamsport. In its history it has undergone marked changes due to adjustment. The large meanders at the west are probably inherited from its winding course on the old Harrisburg Peneplain. The variation in course to the northeast at Cacapon Mountain is further described in the discussion of Cacapon River.

The peculiar bend in the river to east and south near Falling Waters may find an explanation in readjustment. Prospect Hill is thickly strewn with river boulders, and to the southeast of the hill is a deep wide valley which has every appearance of a stream valley to-day, but does not include any creek or run. The conditions of topography in this section would suggest an old course of the Potomac running southeast to Falling Waters where it joined the present course. Conococheague Creek, with its very prominent meandering course, probably emptied into the old Potomac at Falling Waters, with the Little Conococheague tributary from the west near Williamsport. By the cutting down of this stream, the Potomac was tapped near dam No. 5 and deflected to its new course. The high-level gravels of Prospect Hill are on the Somerville Peneplain, so the change was probably post-Somerville.

TERRACES.—The Potomac is bordered by an alluvial terrace over a large portion of its length on the border of these three counties, a terrace composed of silt, sand, and fine gravel and it represents the flood-plain of the river. At 500 feet toward the east and rising to 700 feet near Pawpaw is a second quite a different appearance to the upper two-thirds, and shows a different history. The lower third of the course with its many meanders has the character of a mature stream; while the upper two-thirds in a fairly straight course with steeper fall, rapids, and small waterfalls, has the characteristics of a youthful river. Its upper course is mostly through limestone, while the lower courses are for the most part through shales, but broken here and there by masses of hard strata.

The average fall from 1800 feet at its source to 430 feet at the Potomac would be 13.7 feet to the mile, but the gradient of its channel varies in different parts and is highest in the upper reaches of the river. From its source down to Wardensville, 35 miles, the fall is 700 feet, or 20 feet to the mile; from Wardensville to Capon Bridge, a distance of 24 miles, the fall is 350 feet, or 15 feet to the mile; from Capon Bridge to Forks of Cacapon is 10 miles with a fall of 170 feet, or 17 feet to the mile; from the Forks to Spring Ford in Morgan County is 20 miles, with a fall of 120 feet, or 6 feet to the mile, a very abrupt change in the gradient, part of which may be accounted for by error in the contours on the old reconnaissance atlas sheets which cover the portion of the area on the Winchester sheet of the U. S. Geological Survey. From Spring Ford to Harland Ford, however, a distance of 2.5 miles. the accurate new Government sheets show a fall of 20 feet or 8 feet to the mile; from Harland to Rock Ford, three and a half miles, the fall is 20 feet or 5.7 feet to the mile; and from Rock Ford to the mouth of the river, 7 miles, the fall is 70 feet, or 10 feet to the mile.

While the meandering lower course would suggest a river in maturity with its work well completed, the slopes of the channel show that the river is still engaged in active work of erosion of the channel, and its characters are more youthful than its course indicates, a fact which will again be referred to in the discussion of the history of this river. When the rock structure of this channel is examined, the changes of gradient in its different portions find an explanation. From the south line of Morgan County to Spring Ford, the average fall per mile is 6 feet, and the course is over Devonian Shales, where rock conditions are favorable to erosion, and the stream reaches a temporary base-level with reference to that portion of the river cutting the hard Oriskany Sandstone at Ziler Ford and the limestones down to Harland Ford. The fall along this area of hard rocks is 8 feet to the mile. From this place to Rock Ford, the fall is only 5.7 feet to the mile where the river is cutting into the more or less siliceous Tonoloway Limestone. Near Rock Ford the river impinges on the Oriskany Sandstone and is deflected to the east across the limestone forming rapids over the hard sandstone (Keefer). It then passes into the soft Clinton Shales and the gradient increases to 10 feet to the mile down to the alluvial plain of the Potomac.

After passing across Tonoloway Ridge at Ziler Ford, the river follows along this ridge cutting into it in places with high vertical walls of scenic grandeur, and depositing here and there narrow belts of alluvium on its east bank. After its deflection by the Oriskany Sandstone near Rock Ford, the river bends toward Cacapon Mountain, cutting into it at Edes Fort which is left as an outlier of hard quartzite on its west bank.

It again cuts into Tonoloway Ridge with a large but narrow ox-bow bend where the power-plant is now located. The electric power company has here cut a tunnel and ditch across the narrow neck of land connecting the two portions of the bend, giving a fall of twenty feet in a distance of one-eighth of a mile. The river is again deflected near its mouth by the fluted Keefer Sandstone rocks on the slope of Cacapon Mountain. Over most of the course the river is bordered by high precipitous cliffs. At the south of the Pawpaw sheet on Tonoloway Ridge, the cliffs rise to a height of 300 to 500 feet, with the river at their base, while on the east side is the steep Cacapon Mountain rising to a height of 1600 feet above the river, with its slopes trenched by steep mountain streams that flow at right angles to the mountain down to the river. Their fall would be about 250 feet to the mile so that in the rainy season they are filled with torrential waters, and at other times are small runs fed by mountain springs. They have cut steep walled valleys that gash the mountain side and expose the red Medina Sandstone below the heavy cover of white Medina quartzite. From Rock Ford north the river wall is on the at the source is 1100 feet and at the mouth, 400 feet, or an average fall of 17 feet to the mile. The fall from its source to the south end of the Pawpaw Quadrangle, 13 miles, is 26 feet to the mile; from this point to Rock Gap, 1.5 miles, the fall is 20 feet to the mile; from Rock Gap Run to Smiths Crossroads is 7.5 miles with a fall of 100 feet, or 13.3 feet to the mile; from Smiths to near Stohrs Crossroads, 11.5 miles, the fall is 100 feet, or 9 feet to the mile; from Stohrs to the Potomac, 9 miles, the fall is 100 feet, or 11 feet to the mile.

Near the south edge of the Hancock Quadrangle, Sleepy Creek is joined by the north-flowing Middle Fork with its tributary South Fork. The river or creek channel is cut into the Jennings Shales and Catskill Red Shales and is bordered by alluvial flats. It follows the general trend of the rock formations and is a type of consequent stream. Its drainage basin is broad, extending from Sleepy Creek Mountain to Pious Ridge on the west, with a width of four to five miles. Its tributary creeks and runs on the west cut through transverse valleys in the ridges to join the main stream, and thus suggest a modified drainage system probably due to backward cutting into the ridges and the tapping of Warm Spring Run tributaries. These transverse valleys are seen in Swim Hollow Run, Yellow Spring Run, Rock Gap Run, and other runs shown on the map, but unnamed.

On the east side of the main creek, the large tributaries follow the rock structure as subsequent streams, the largest being Mountain and Meadow Branch Runs. Mountain Run drains the west slope of Sleepy Creek Mountain, sending its small branches back to the foot of the mountain. It follows the course of the mountain and lies between it and Highland Ridge. Its length is 6 miles with a fall of 410 feet, or 68 feet to the mile. Meadow Branch Run drains the valley between Sleepy Creek Mountain and Third Hill Mountain from the Locks of the Mountain to their northern end. In its upper portions, it is now only a small run fed by springs, but it gradually increases in volume and leaves the mountains as a swiftly flowing stream of good volume, passing over the falls and rapids, characteristic of a youthful stream. At the north end of the mountains, it passes through a deep vertical walled gorge in the Carboniferous sandstone through most rugged and wildly picturesque scenery at the Devils Nose and above. The length of Meadow Branch Valley is 14 miles and it is nearly a mile wide, composed of soft red and buff shales, a very fertile valley at the present time abandoned in cultivation. The run falls 420 feet from Myers to the Devils Nose in a distance of 8 miles, or a fall of 52 feet to the mile. From this point to the mouth, 2.5 miles, the fall is only 9 feet to the mile. The course of the stream is slightly winding and it has built up small alluvial flats. As it impinges on the hard sandstone at the north, it is deflected eastward a short distance, then passes north between the two mountains.

At Johnsons Mill, Sleepy Creek has cut across an old ox-bow. The old channel is seen to the north of the present stream at the old mill and it passes to the south in a broad curve around a rocky shale hill in a valley now marked by a floor of silt, sand, and fine gravel. The creek cuts across the narrow portion of the big curve and passing over rapids, falls into the old channel which is a deep pool at this place and curves abruptly to the north. The bank of the creek at this pool is vertical and somewhat undercut. It is composed of cliffs of Devonian Shales and is a scenic point which attracts many visitors during the summer.

ROCK GAP RUN.—This western tributary of Sleepy Creek has cut a deep gorge through Warm Spring Ridge near the south end of the Pawpaw Quadrangle. It is at the present time a very small run, probably the successor of a much larger stream in earlier time that may have drained the Sir Johns Run Valley, but by the deepening of the valley of the Potomac after its course was changed through Tonoloway Ridge, the Potomac tributary probably captured the headwaters of Rock Gap Run.

SIR JOHNS RUN drains the valley between Cacapon Mountain and Warm Spring Ridge. It follows a course parallel to these ridges and it is a subsequent stream with a length of 8 miles and a fall in that distance of 540 feet, or nearly 70 feet to the mile. The valley is narrow, its branches short, volume of water small, except after rains, and it reaches the Potomac at Sir Johns Run Station.

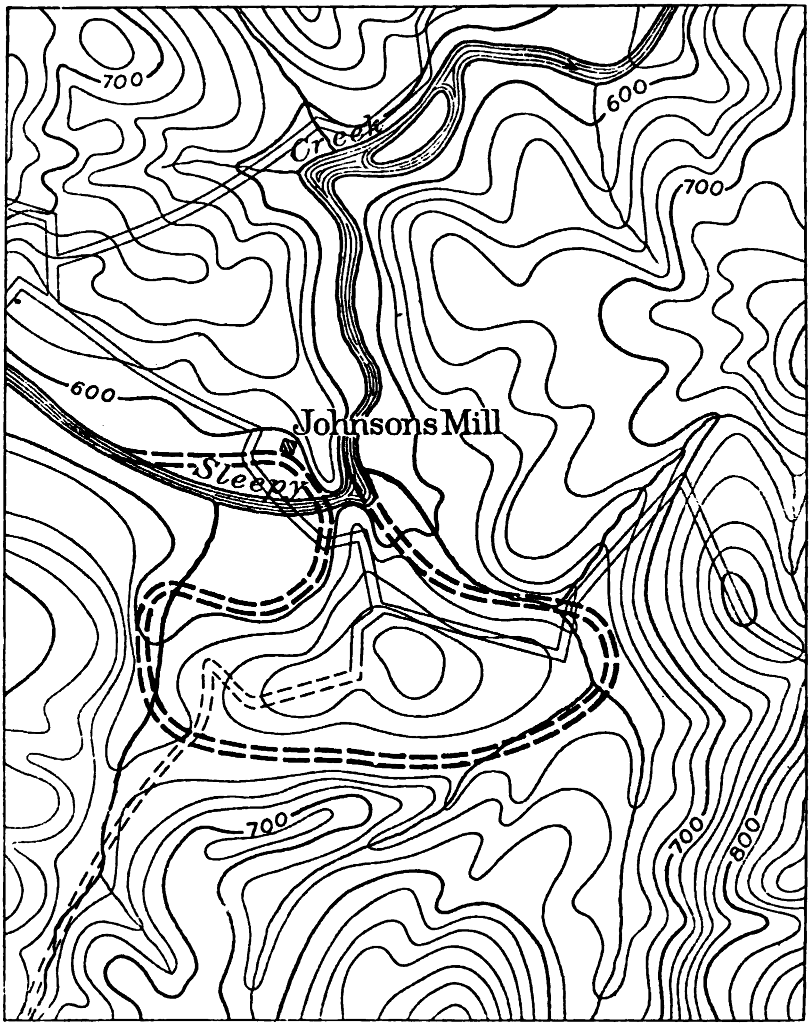

Figure 6. Ox-bow cut-off in Sleepy Creek at Johnsons Mill, Morgan County.

WARM SPRING RUN drains the valley between Warm Spring Ridge and Horse Ridge. It has a length of 11 miles and a fall of 420 feet, or nearly 40 feet to the mile. It follows close to Warm Spring Ridge and is fed by various springs, especially by the warm springs at Berkeley Springs. On the east it has a number of short tributaries which extend into the divides separating them from the Sleepy Creek drainage. Its lower course is winding, and it reaches the river at Brosius, opposite Hancock, Maryland.

BACK CREEK.—Back Creek is a subsequent stream with its source near Lafolletsville in the southeastern part of Hampshire County, from which place the creek flows northeast across Frederick County, Virginia, thence across Berkeley County, West Virginia, along the west slope of North Mountain, reaching the Potomac at a point about half-way between Cherry Run and Little Georgetown. Its air-line length is 38 miles and the channel length is 57 miles. The average fall from source to mouth is 15 feet to the mile, or a total fall of 840 feet. In its upper portion down to Rock Enon Springs, a distance of 10 miles, the fall is 500 feet, or 50 feet to the mile. In the next 9 miles to Gainesboro, the fall is 11 feet to the mile. From the south line of Berkeley County to near Tomahawk, the distance is 20 miles with a fall of 60 feet, or 3 feet to the mile; from this place to the Hedgesville road is 3¼ miles with a fall of 40 feet, or 12 feet to the mile; and in the 8½ miles from this road to the mouth of the creek, the fall is 40 feet, or 4.7 feet to the mile. The channel on the Hancock Quadrangle is cut in the Devonian Shales and is a meandering one with quite symmetrical curves. The alluvial flats are well developed at various places, reaching a width of a quarter mile, but they are not continuous, being broken by canyon-like walls which come down to the water's edge. The land slopes to the west from the creek, while on the mountain side are high cliffs of shale often vertical. A series of gravel terraces at the 500-foot level along the stream indicates the old level of the Somerville Peneplain where its meanders were probably formed, and during the later elevation the winding course was maintained.

The gradient of this stream valley with its steep mountain slope and low fall near the mouth is normal, but an exception comes into the course from the county line to near Tomahawk, where the fall is only 3 feet to the mile, while on each side of this area, the fall is 11 to 12 feet. This is possibly due to the narrow gorge obstruction in the channel just north of the Hedgesville road which impounds the water back nearly to Tomahawk, thereby making a temporary base-level for the Tomahawk portion of the creek. Back Creek is fed by numerous short tributary runs on both sides. In Berkeley County, it has only one long feeder, Tilhance Creek, which empties into Back Creek two miles from its mouth. This stream and its branches drain a large area in Back Creek Valley.

TILHANCE CREEK has its source in the foot-hills of Third Hill Mountain and flows northeast to south of Baxter, where it turns abruptly to the east and then northeast parallel to Ferrel Ridge, bending around the north end of this ridge in a transverse valley at Soho, then northeast to Back Creek. Its length is 9 miles with a fall of 400 feet in that distance, or 45 feet to the mile. It is a stream of small but steady volume in ordinary weather. Its eastern tributaries follow longitudinal valleys parallel to the main run and also to the ridge, while its western tributaries run at right angles to the main stream and have cut deep narrow valleys into the mountain This arrangement of parallel tributaries on the east, and transverse on the west, is a striking feature of this drainage basin.

CHERRY RUN has its source on the slopes of Paines Knob and follows a transverse high valley between the two northern portions of Third Hill Mountain known as Hedges and Short Mountains. At the eastern foot of the mountain, the run leaves the transverse course and bends northeast to another transverse valley near Holton, then northeast to the Potomac below Cherry Run Station. Its length is 7 miles with a fall of 780 feet, or 111 feet to the mile. In the first 1.- miles of its mountain course to the foot of the mountain, the fall is 300 feet to the mile, and from here to the mouth of the run the fall is 60 feet to the mile. The lower half of its course from Holton down has a fall of 35 feet to the mile, so that its channel is steep through most of its course. Cherry Run from its mouth to its source forms the boundary line between Morgan and Berkeley Counties.

The eastern slope of North Mountain is drained by Harland Run and its branches. This run is fed by some very

PLATE V.—One of the Limestone Good Roads in Jefferson County, with Typical White Elm Developed Without Crowding.

large springs at Harland Spring Farm and at Spring Mills, and formerly furnished water-power for the mill at the latter place. It reaches the river at Little Georgetown.

OPEQUON CREEK.—The next large stream in the area eastward is the Opequon which reaches the Potomac east of Bedington. Its source is on the east slope of Little North Mountain west of Winchester, Virginia. It flows south and east to Bartonsville, 5 miles south of Winchester, thence northeast, passing 5 miles east of Winchester, thence by Wadesville into Berkeley County, West Virginia, passing 2 miles east of Martinsburg, and reaches the Potomac 2 miles east of Bedington. The distance from its source to its mouth is 34 miles air-line, but by the channel it is 65 miles. It follows the limestone valley in a winding course with low grade. Its headwaters pass down a slope of 18 to 22 feet to the mile to a point east of Winchester; from this place to a point west of Kearneysville, a distance of 25 miles, the fall is 100 feet, or 4 feet to the mile; from this point to the mouth of the creek, 20 miles, the fall is 70 feet, or 3.5 feet to the mile; so that the average fall of the stream from Winchester is less than 4 feet to the mile. Opequon Creek drains practically all of Berkeley County east of North Mountain. Its tributaries are mostly small, the larger being Middle Creek, east of Darkesville, Mill Creek near Bunker Hill and Gerrardstown, Tuscarora and Dry Run near Martinsburg.

These tributary runs have their sources in or near North Mountain. **Middle Creek** has its source on the North Mountain east slope near Grantham, and flows southeast past Darkesville to the Opequon west of Leetown. Its length is nearly 10 miles with a fall of 300 feet, or 30 feet to the mile.

Mill Creek has its source in Frederick County, Virginia, and follows a northeast course to Gerrardstown and then flows southeast past Bunker Hill to the Opequon. Its length in Berkeley County is 13 miles, with a fall of 310 feet, or 24 feet to the mile. It is used for water-power at the Bunker Hill Mill. **Evans Run** rises just north of Pitzers Chapel and near the source of the Tuscarora, but flows nearly east to the Opequon west of Van Clevesville. Its length is 2.75 miles and its fall is 12.4 feet to the mile. This run receives its largest supply from Big Spring, two miles south of Martinsburg.

Tuscarora Creek has its source near Pitzers Chapel, northwest of Arden, and flows northeast parallel to the mountain to near Nollville, where it turns east by Martinsburg and reaches the Opequon near where the Baltimore and Ohio Railroad crosses that creek. Its length is 12 miles, with a fall of 280 feet, or 23.3 feet to the mile. A number of mills are run by water-power from this creek near Nollville, Martinsburg, and east of this city. The north branch of the creek is known as **Dry Run** with a length of 6 miles. The tributary runs on the east side of the Opequon are small, the largest being **Hopewell Run** at Leetown, and **Turkey Run** at Middleway.

Rock Marsh Run has its source near Kearneysville and flows nearly north past Scrabble, reaching the Potomac River near dam No. 4. Its length is 9 miles, with a fall of 20 feet to the mile. It is fed mainly by the large Wynkoop Spring on the Martinsburg-Shepherdstown Pike, and from this point north to the river, the run forms the boundary line between Berkeley and Jefferson Counties. One mill is located on this run, 1.5 miles south of Scrabble.

SHENANDOAH RIVER.—The Shenandoah River is formed by the union of the North and South Forks at Riverton, north of Front Royal, Virginia, and flows northeast 34 miles to the south line of Jefferson County, West Virginia. It then flows 20 miles along the eastern side of Jefferson County to the Potomac at Harpers Ferry, a total length of 54 miles, with a fall of 100 feet from the southern line of Jefferson County to the Potomac, or 5 feet to the mile, while the average fall for its whole length is 3 feet.

The South Fork has its source just southeast of Greenville in Augusta County, Virginia, and is 126 miles long to Riverton. The North Fork rises seven miles north of Harrisonburg, Virginia, and is 66 miles long to its junction with the North Fork at Riverton. The river flows in a winding channel on both forks and on the main river, and it is the largest river in the area except the Potomac. In West Virginia, the river has a number of long branch runs from the west, and short tributaries from the east as the channel is close to the foot of the Blue Ridge.

The largest tributary run on the east is **Furnace Run** in the southeast corner of Jefferson County, which flows north in a longitudinal valley in the Harpers Shale from near Wilson Gap to the river east of Shannondale. Its fall is 100 feet to the mile over a very rough channel with numerous small waterfalls.

On the west in the southern part of Jefferson County is **Long Marsh Run,** which rises near Rippon, and flows southeast 7 miles to the Shenandoah at Boyds Ferry. At Kabletown is **Bull Skin Run,** its north fork rising south of Aldridge, and the south fork near Summit Point. Its length is 12 miles with a fall of 20 feet to the mile. At Kabletown, a dam of 14 feet yields 8 horse-power.

Evitts Run has its source west of Aldridge and flows east of Charlestown, thence south and east to the river at Bloomery. Its length is 14 miles, with a fall of 10 feet to the mile to Charlestown, then 20 feet to the mile to Bloomery. A dam of 16 feet in height on this creek at Charlestown gives 18 to 20 horse-power, while another on the Kabletown Pike with a height of 36 feet yields 45 horse-power.

Flowing Springs Run has its source to the north of Charlestown and receives its greatest amount of water at Flowing Springs, two miles northeast of that city. It flows past Halltown to the river at Millville, with a length of 10 miles and a fall of 24 feet to the mile. Several mills were formerly run with the water-power from this run.

The **Shenandoah River** did not always follow its present course and in its past history has undergone a process of adjustment. The former course of the river was apparently across the Blue Ridge through Snickers Gap, 8 miles east of Berryville, Virginia, and the river pursued a course eastward nearly parallel to the Potomac. This alteration of course to the northward as the Blue Ridge area was uplifted was first worked out by Willis, whose description of this diverted course has become a classic illustration of stream capture, and it is here quoted from his article on the North Appalachians:[3]

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[3]Nat. Geographical Soc., Monographs, Vol. I, No. 6, p. 191; 1895.

"The Potomac traverses the Blue Ridge at Harpers Ferry. South of this water gap are several wind gaps, such as Snickers Gap, which mark the channels of ancient streams, now diverted. The Shenandoah River enters the Potomac above the water gap at Harpers Ferry, flowing northward along the western base of the Blue Ridge. The streams which passed through Snickers Gap and the other wind gaps ran above the present course of the Shenandoah, crossing it about at right angles. The two drainage systems could not exist at one time; therefore, it is evident that the older one has been replaced by the younger river, the Shenandoah. This diversion took place by the gradual growth of the Shenandoah from its mouth southward. The Potomac, the larger stream, cut its water gap faster than Snickers Gap was cut. The Young Shenandoah of the Kittatinny (Schooley) Plain, a small tributary of the Potomac where the mouth of the present Shenandoah is, acquired considerable fall as the Potomac deepened its gorge, and sawed its channel down rapidly in the limestone, which offered no great resistance. But the stream in Snickers Gap, with perhaps less fall and not much greater volume than the Shenandoah, had to saw much harder rock in crossing the Blue Ridge. Its channel remained high, therefore, as compared with that of the Shenandoah. The latter extending its headquarters backward as a tree puts out new twigs, eventually tapped the channel of the other stream above Snickers Gap. The waters above the point of attack joined the Shenandoah; the section between the point of attack joined the Shenandoah; the section between the point of attack and Snickers Gap was reversed as the Shenandoah rapidly deepened the channel of its new conquest; and the lower portion of the stream, now called Beaverdam Creek, having lost its original headwaters, took its rise at Snickers Gap. Thus the ancient stream which once flowed through the gap was divided into three sections,—the diverted, the inverted, and the beheaded,—while the Shenandoah, the diverter, was strengthened. By successive captures of this kind, the piratical diverter has grown, until it is now the largest of the rivers within the valley; and its headwaters approach the channel of the James, which it may in time add to its conquests. . . . The combined waters are working rapidly to reduce the surface of the Shenandoah Plain, while the Blue Ridge remains subject only to the attacks of rains and tiny rills. Adjustment of streams not only establishes divides on the hard rocks, but also diverts the waters that are cutting across them."

TOPOGRAPHY OF THE EASTERN PANHANDLE AREA.

For purposes of topographical description, the eastern Panhandle area may be divided into three divisions: Mountain Area, Ridge Area, and Valley Area.

THE MOUNTAIN AREA.—From Cacapon Mountain to the west is a series of northeast-southwest rugged mountains separated by narrow valleys. The mountain slopes are gashed by steep runs giving a very rough topography which continues on to the west of the area under discussion. At the western side is the narrow Potomac Valley, the river following a northeast course parallel to the trend of the rocks, but in a strongly meandering channel. This valley is bounded on the west by Town Hill; and on the east by Spring Gap Mountain, Purslane Mountain, and Sideling Hill. The eastern mountains have steep and highly dissected slopes down to the river. The fall from the top of the mountains to the river is 1220 to 1400 feet in a distance of one to one and a half miles, which results in deeply trenched valleys in these mountain runs in the Catskill Red Shales and soft Red Sandstones. The erosion is most active and the valleys are really steep-walled canyons making a rugged landscape with the slopes heavily wooded along the runs. In the valley are numerous flat-topped hills of about 800 feet elevation, which represent the remnants of the old Somerville Plain. Another series of hills reach 900 to 1000 feet and are probably capped by the remnants of the Harrisburg Peneplain.

The Baltimore and Ohio Railroad follows close to the river and where it leaves the river valley, the road is tunneled through the hills. The air-line distance in this valley from Pawpaw to Lineburg is ten miles; by the river channel, the distance is 26½ miles, and by the old line of the railroad it is 18 miles. The new railroad line cuts across the river bend from Hansrote to Magnolia with one tunnel and three river bridges, joining the old line above Pawpaw, cutting off nearly six miles in distance and reducing the length of line from Pawpaw to Lineburg to twelve miles, very nearly the air-line distance.

Spring Gap Mountain extends from Hampshire County into Morgan for a distance of three-fourths mile, southeast of Pawpaw. It is a level-topped mountain of 1800 feet elevation, which may represent the old Schooley Peneplain, as this level is also found on Sideling Hill. Its slopes are steep but not so much cut by erosion as the larger mountain to the north.

Purslane Mountain and Sideling Hill are really the same mountain separated by a high-level valley of erosion whose level at the north end is 1600 feet and 1100 feet at the south end. It is drained by Rockwell Run. Purslane Mountain on the west side of this valley has a level top, 1700 to 1800 feet altitude, rising southward to 2000 feet. The highest point is 2008 feet, near the south line of the Pawpaw Quadrangle, with peaks at the north 1893 and 1988 feet. Its west slope is deeply trenched by the short steep runs forming very rugged slopes, while on the east slope erosion has not been so active. The fall of the slope on the east and west sides is 800 feet to the mile so that the mountain is very symmetrical, but the numerous runs on the west are absent on the east.

The hard Carboniferous sandstone cover of the mountain extends 200 to 300 feet lower on the east side than on the west, which would protect the east slope to a large extent from the erosion as found on the west side, also the valley on the east side of the mountain is 200 to 300 feet higher than the Potomac on the west. The sandstone debris from the mountain extends down into the valleys and the whole mountain is rugged and rocky, with large sandstone cliffs projecting, and there is practically no tillable land on the mountain, so that it is unsettled and represents to-day so much waste land. The mountain is cut by the deep gap at the north where the Potomac cuts through.

The valley east of Sideling Hill is separated into two parts by a low transverse divide 800 to 900 feet above the sea. This probably represents the remnants of the Harrisburg Peneplain which is also preserved in the terraces along the foot-hills of Sideling Hill, well shown on the terrace just west of Woodmont at 900 feet elevation. From this divide, which is five miles south of the Potomac, the run flows south and east to Sleepy Creek, and north to the Potomac, the south-flowing streams being about one-half as long as those to the north. From the greater width of these north-sloping valleys, especially well seen in Long Hollow, the drainage of a former time probably all flowed north in this valley. The valley contains two northeast-southwest ridges, Bare and Road Ridges, whose level tops are about 800 feet above the sea, and are protected by the hard Devonian reddish sandstone and conglomerate of the Jennings Division.

The east side of the valley is bounded by Tonoloway Ridge, reaching a height of 1000 to 1100 feet, capped by the Oriskany Sandstone, and probably represents a remnant of the Harrisburg Peneplain on this more resistant sandstone. Its eastern slopes are almost perpendicular walls to the Cacapon River. It is cut by a wide gap at the south where the river passes through, and by a gap three-fourths mile wide at the north where the Potomac has cut through. The limestones under the sandstone form the eastern wall of the river, while the western slope is composed of Devonian Shales. The trend of the ridge, like that of the mountains and ridges to the west and east, is about north 25 degrees east.

Cacapon River flows in a narrow valley between Tonoloway Ridge and Cacapon Mountain, keeping close to the former as far north as Rock Ford, then following the mountain. Its west wall is precipitous and its eastern wall rises to Cacapon Mountain by a steep slope, 1460 feet in one and a fourth miles. The river follows a moderately meandering course, with large meanders near the Potomac.

Cacapon Mountain, the highest mountain in the area, in reality begins southwest of Sir Johns Run on the Potomac as a ridge 600 feet high, carrying a remnant of the Harrisburg Plain at 800 to 900 feet, and then rises in four miles to 1545 feet at Prospect Rock. Its level top at 2000 to 2100 feet probably represents the old Schooley Peneplain, and the mountain reaches its highest point in the northern area, 2196 feet, five miles southwest of Prospect Rock. It is 2320 feet at the north line of Morgan County. The level top shows a gradual rise of about 100 feet to the mile southward with a width of nearly one-half mile. It is capped by the soft Clinton Shales from one mile south of Prospect Rock, while the northern portion is mantled by the hard Medina white quartzite. The west slope is deeply eroded by deep cross valleys of erosion, while the east slope near the south end of the Pawpaw Quadrangle in Piney Ridge, a 1200-foot shelf, may represent a remnant of the Weverton Peneplain which is also seen across the valley on Warm Spring Ridge near Rock Gap.

RIDGE AREA.—From Cacapon Mountain east to North Mountain is a broad valley broken by parallel low ridges following the same course as the mountain and of low altitude. At the center of this broad valley are two mountain ranges which die out northward four or five miles south of the

Potomac. While to the west of Cacapon Mountain, there are long narrow valleys bounded by high ridges or mountains, to the east of this mountain there is evidence of the same arrangement of long narrow valleys separated by parallel ridges and mountains, but in this section Sleepy Creek has cut here and there across these ridges, capturing the inter-ridge drainage, so that the broad drainage area of this creek is carried by transverse as well as by longitudinal valleys and the old plain is more highly dissected. The result of these changes is a very different type of topography to that west of the mountain.

Warm Spring Ridge extends from the south line of the county to Hancock and beyond in Maryland. It is capped by the Oriskany Sandstone, over much of the area snow-white in color, which also forms its eastern slope near the top of the ridge, while on the western slope the limestones are found. The ridge is level topped at a level of 800 to 900 feet above the sea to southwest of Hancock Station and represents the Harrisburg Plain. At the south, the top stands at 1200 feet, possibly on the old Weverton Peneplain. Its slopes, while steep, are more so on the east than on the west, and the valley between this ridge and Cacapon Mountain is narrow with steep slopes, and it is drained to the north by Sir Johns Run from a divide at a level of 940 to 950 feet, from which the shorter Rock Gap Creek flows south and east through a gap in the ridge to Sleepy Creek. The width of this valley and the present width and depth of Rock Gap suggest a drainage of the valley to the south through the gap with a probable reversal of the drainage to the north in late geological times by stream capture. At the south, this valley is drained by the north-flowing Indian Run. The eastern slope of the ridge is drained by the north-flowing Warm Spring Run, a straight channel stream to Berkeley Springs, then very winding to the Potomac, opposite Hancock. The valley of this run at the north is bounded on the east by Horse Ridge, a long level ridge of 800 feet elevation, on the old Harrisburg Plain. Further south this ridge is continued in the form of isolated hills of 900 feet elevation, but erosion has destroyed the ridge as a continuous line in the topography.

East of Horse Ridge at the north is the valley of Dry Run, then Pious Ridge, 600 to 700 feet in elevation, reaching 800 feet, east of Berkeley Springs. The northern portion is probably the remnant of the Somerville Plain and further south represents the Harrisburg Plain. The broken continuations of this ridge to the south are Wolf Hill and Timber Ridge, 900 feet elevation, also parts of the Harrisburg Plain. Sleepy Creek cuts a gap through Timber Ridge.

Sleepy Creek lies in a winding valley parallel to the ridges, and its branches on the west have cut into and across the bounding ridges in transverse valleys. This feature is illustrated by Rock Gap Run, Yellow Spring Run, Swim Hollow Creek, and other streams unnamed. On the east at the south end of the Hancock Quadrangle, the stream valley is bounded by Highland Ridge, 900 feet elevation, another remnant of the Harrisburg Peneplain. The area between this ridge and Sleepy Creek Mountain is drained by Mountain Run, one of the two long tributary streams from the east. The tributary runs on the east follow the direction of the main creek valley and join it in the direction of the water-flow rather than at right angles as they do on the west side. There is also a large number of small runs trenching the ridges and following short and steep courses to the main creek, similar to the short runs to the Potomac in the western part of the county area. The stream and ridge topography are thus similar to that of the mountain area to the west, but on a more subdued scale. The Potomac River bluffs at the north show the continuation of these broken ridges. In that section, they are still further divided by deeply cut valley runs directly tributary to the Potomac.

Sleepy Creek Mountain ranges in height from 1000 feet at the north to 1700 feet and reaches a height of 1800 feet toward the south end of the Hancock Quadrangle, and further south to the county line. It is level-topped and probably represents the Schooley Plain. It is capped by the hard Carboniferous sandstones and its crest is taken as the county line between Morgan and Berkeley southward from a point one and a half miles north of Whites Gap. Its slopes are steep and rugged, not cut by run valleys as are the mountains further west.

Meadow Branch Valley to the east of Sleepy Creek

Mountain is cut in the Carboniferous Shales. It is fairly broad at the south, but at the north passes between canyon sandstone walls in a wildly scenic region at the Devils Nose and to the north and south of that place. The run is bordered in places by narrow alluvial benches. It is fed by numerous springs and small tributary short runs, and it empties into Sleepy Creek just beyond the north end of the mountain.

Third Hill Mountain forms the east wall of Meadow Branch Valley. This mountain at the north, known as Short Mountain, has a level top of 1300 feet elevation, probably on the Weverton Peneplain. The level of the main mountain further south is 1700 feet, which is low for the Schooley Plain and may represent a minor halt in that erosive cycle. Pinkerton Knob reaches a height of 1777 feet, not as high as the level top of Sleepy Creek Mountain. The mountain top is covered by the Carboniferous sandstones and conglomerate and is very rough and craggy. Its slopes are steep, both on the east and on the west, and on the east side the slope is deeply cut by ravines. At the north end both mountains bordering the valley die out at the Meadow Branch.

Five and a half miles north of the Virginia Line, the Meadow Branch Valley Syncline rises and the mountains are united at the "Locks of the Mountain", with an elevation of 1830 to 1840 feet. South of this point, Sleepy Creek Mountain extends south a short distance into Virginia with the same elevation as to the north, but Third Hill Mountain rises rapidly from 1800 to 2200 feet and ends two miles north of the State Line. The area between the mountains south of the "Locks" is drained by the southward flowing Little Brush Creek.

East of this mountain area is the broad Back Creek Valley, cut by low ridges so dissected by streams as to lose their ridge character except in Ferrel Ridge, and its continuation in Wilson Ridge. The valley west of Ferrel Ridge is drained by Tilhance Creek and its tributaries which form a branching drainage network. This stream follows the trend of the rocks as a subsequent stream to the north end of Ferrel Ridge, and then cuts across the rocks to Back Creek. At the north end of Back Creek Valley, the drainage is mainly through the transverse valley of Cherry Run, which reaches the Potomac near the station of the same name.

The hill remnants of an old sandstone ridge are seen parallel to the mountains from Parkhead, Maryland, to the south, running three-fourths mile west of Holton, and the same distance west of Baxter, three miles west of Tomahawk, to the south end of the Hancock Quadrangle, with an elevation of 600 feet at the north and 700 feet at the south, and probably on the Somerville Peneplain. The runs, cutting across this old ridge in transverse valleys, follow longitudinal valleys to the west of the ridge, as shown by the course of Big Run to the north of Cherry Run.

Ferrel Ridge and Wilson Ridge are steep sided ridges, capped by the Oriskany Sandstone and underlying limestones and are bordered by Oriskany Sandstone. Ferrel Ridge reaches an elevation of 800 feet, the Harrisburg Plain, and it is divided by a longitudinal valley, which is a branch of Tilhance Creek Valley, into two ridges at the south. It is also separated by two transverse valleys, one at Tomahawk, and one, one and a half miles north. The ridges to the south of the Tomahawk Valley are 740 to 780 feet in elevation. The hills to the north of Ferrel Ridge at Soho are 500 feet elevation, and are probably on the Somerville Peneplain.

East of Ferrel Ridge is the valley of the stream of Back Creek, bounded on the east by the Little North Mountain. This valley has a gradual slope westward to Ferrel Ridge, and on the east is bordered by the steep walls of North Mountain. The valley is crescentic-winding, and is cut into the Devonian Shales with fringes of alluvium terraces on the bends of the creek, but these terraces are not continuous. From near Shanghai south, the alluvial flats are larger and continuous.

Little North Mountain forms the eastern boundary of the Back Creek Valley. The height of the mountain at the south end of the Hancock Quadrangle is 1200 to 1260 feet above sea, and further south, 1400 to 1500 feet. It is capped by the hard Medina white quartzite, and it may at the north represent a portion of the Weverton Peneplain. Near Hedgesville, the elevation is 960 feet and it is cut by the Hedgesville Gap to 600 to 660 feet above sea. North of the gap, the height is 700 to 800 feet, with one peak 900 feet in elevation. The 800-foot level probably represents the Harrisburg Plain. The mountain is again broken by a slight gap north of North Mountain Station, where the railroad passes through, and another gap is seen one mile further north where the county road passes through. These northern broken portions of the mountains are level topped at 600 feet elevation, and represent portions of the Somerville Peneplain on which are peaks reaching an elevation of 720 to 740 feet. At the Potomac River Gap of the mountain, the vertical walls on the south are 500 to 600 feet in elevation.

Further south, the mountain, 1500 feet in elevation, is cut by the shallow Boyds Gap (1478 feet), Mills Gap west of Gerrardstown (1083 feet), Dutton Gap (1294 feet). The county roads cross the mountain southeast of Tomahawk at 1040 feet, and at Boyds Gap and Mills Gap at 1478 and 1083 feet, respectively.

The mountain slope on the west is composed mainly of Devonian Shales with thin belts of Oriskany Sandstone and Clinton Shales near the top, and it is cut by deep valleys of small runs. The east slope, capped by the hard red Medina Sandstone, with lower slopes of Silurian Shales and Limestones, is steeper than the west slope, and is less cut by erosion.

GREAT VALLEY.—East of the North Mountain is the Great Valley, extending to the Blue Ridge at Harpers Ferry, northward into New York State, and south to Alabama. In the Berkeley and Jefferson County Area, it is a valley marked by low hills and ridges and minor small valleys occupied mostly by small runs. The valley floor is limestone at the west, and limestone and shales eastward. The shale area is marked by rounded hills of steep slope deeply trenched by the small valleys, while the limestone area has a more rolling topography, with hills of more gentle slope giving more rounded outlines. The relief varies in elevation from about 400 to 600 feet, but will average around 500 feet, which level represents the Somerville Peneplain. To the eye where only a limited area of the valley is visible, the hills seem to present no regular arrangement; but when the topographical map is studied, these high points are found to occur along northeast-southwest lines and represent remnants of ridges which were characteristic in the area to west of North Mountain. In that area the ridges were more dissected by erosion than in the ridge area west of Cacapon Mountain, and in the Shenandoah Valley as represented in Berkeley County, the ridges are still more broken by erosion so that the ridge character is nearly gone.

This limestone valley is one of great fertility, an area of valuable farms and prosperous orchards. It is one of the most important agricultural belts in the State. The foot-hills of the eastern side of North Mountain, like those on the east side of Third Hill Mountain, are covered with miles of orchards whose fruit in color and flavor is standard among the orchards of the country and is shipped to various parts of the world.

Except for Opequon Creek, the streams of this valley are small. Near the mountain the area is drained by Harland Run and its long Tulissus Branch, which together have a length of seven and a half miles, reaching the Potomac at Little Georgetown, with an average fall of 30 feet to the mile. The area west of Falling Waters is drained by Falling Waters Run, but most of the northern area of the Valley is drained by runs of short length, or by small runs fed by springs, except after heavy rains. This Great Valley has been formed by the solution and erosion of the limestone and soft shales, while the hard sandstones have protected the mountains on either side.

BLUE RIDGE.—The Blue Ridge Mountains form the eastern border of the area from Harpers Ferry south. These mountains are capped by hard sandstones and have a height of 1000 to 1100 feet at the north and 1600 to 1700 feet at the south line of the county. The western slope is deeply indented in the Harpers Shales and the topography to the river is very rough. The slope is very rocky from the sandstone debris that has rolled from above and the stream valleys are narrow and deeply cut. The elevation at the river is 360 to 380 feet, while the mountain is 1600 to 1700 feet, a fall of 1200 to 1300 feet in a distance of one and a half to two miles.

RESUME.—From the preceding review of topography and stream development in the eastern Panhandle Area, it is seen that there is a great diversity in the surface features, but bound together by a unity of causes of folding, then repeated denudation and uplift. The land sculpture is due to causes not only operative in the past, but also at work in the present. The land area has been reduced to a sea-level plain at least four times, and the forces of erosion are now reducing it toward another peneplain.

The mountains and ridges, so characteristic of the area. are not the result of any supernatural or cataclysmic force at some time in the far distant past, but they have been carved out of an uplifted approximately level plain sloping seaward. by the chemical and mechanical forces of air and water which have removed the softer and more soluble rocks faster than the harder ones. The softer rock areas now usually form the valleys, while the harder strata have protected the hills and ridges.

The drainage system has branched into a network which penetrates the remote recesses of the area. These three counties are located on a high plain or plateau cut and carved until its irregular surface has lost the plain character. Knowing the history as outlined in this Chapter, then imagination can fill for us the valleys with debris to the height of the level-top hills and mountains, and we see again the old plain as restored.

The river, hill, and dale abound in the history of their development, so that he who runs may read the history of a continent in them, a history ever developing and widening in its scope, and ever changing. These forms pass through a life cycle from infancy to old age, and although inanimate, they thus seem to be endowed with energy and life. Geography now has a new meaning, and becomes not merely a study of location of country, city, and river, but includes a study into the reason why. The study of earth's forms in this light of development is one so full of interest and profit that one who has overlooked it has lost much of educational value.

INFLUENCE OF TOPOGRAPHY ON THE DEVELOPMENT OF THE COUNTRY.

The early settlers of this country, coming across the sea, established themselves in settlements near the ocean border, or up the broad river estuaries on the Coastal Plain. As they became more numerous, they followed up the rivers or over the lowlands and established their manors. The line of escarpment of the Piedmont Plateau at the Fall Line marked the limit of easy passage for the boats and rafts and at first marked the western limit of settlements. In later time the utilization of the water-power at this line led to the location of manufactures, and to this day marks the location of the large eastern cities.

In course of time, the settlers moved westward from the escarpment and made new settlements on the higher Plateau, but the mountain barrier marked the western limit for the new peoples, and was named by them from its hazy distant crests the Blue Ridge. The country beyond was an unknown trackless wilderness. The early Virginians were glad to make an agreement with the Indians that they would go no further than the mountains in return for freedom from molestation east of the barrier.

As the years passed on and many people came to the new land of freedom, they worked their way westward at the northern end of the Appalachians, following the Mohawk Valley nearly two hundred miles west of New York by 1775, but in a narrow belt along the rivers. As early as 1730, there were settlements at Easton, Reading, and Lancaster, in Pennsylvania, and roads were opened to connect with Philadelphia. Thus they entered the upper portion of the Great Valley whose richness of soil and easy travel over fairly level land tempted the hardy Scotch-Irish southward to the Potomac and beyond. A main road was established from Lancaster to York, and extended to the Potomac at Williamsport and on to Winchester. As early as 1732 some of these hardy Pennsylvania families moved south to below Winchester and the town was established in 1752. More venturesome pioneers moved further south into North Carolina and later passed through the Cumberland Gap, establishing settlements in Tennessee and Kentucky in 1769. The early history of all this migration was in the Valley from the north and not across the mountain barriers, until after the settlements, when roads were opened through the southern high gaps. The land of the wilderness was moved further westward, bounded at first by the Alleghany Mountains and then rapidly disappeared westward.

This country beyond the mountain in that day was hardly explored by the hunter or the adventurer. Its unknown and nameless terrors were further magnified through fact and imagination. The Potomac was the only river that crossed this mountain barrier and it was not easily navigable. To the west of the Alleghanies down to the time of the War of the Revolution, there was not an English settlement of any extent. Pittsburgh was settled in 1773, but it was only a small collection of cabins. Boone had just established himself and his party in Kentucky. As Brigham states in his book on Geographic Influence in American History (p. 87), "the new Americans were pressed between the sea and the base of the mountains, forced to be neighborly, to assimilate each other's ideas, provide for common defense, and build up common institutions." Within these limits the people increased in strength and by the travel from one part of the country to the other they became more and more united and were in a position to fight for a Union by the time of the great conflict for Independence. Had the mountain barrier been absent and the people thereby more scattered into a greater number of settlements, but less in size and more remote from one another, the history of this conflict might possibly have been quite different.

When the mountains were finally crossed by the wave of the new civilization, the development was rapid on the fertile valley lands into the Ohio Valley and then farther and farther westward. It was in the valleys that the development came first, but when the time came for the recognition of the mineral wealth of the mountains, that country was developed. In due time the valleys and foot-hill slopes became the farming area, and the mountains were devoted to mining and grazing.

PLATE VI.—View up the Potomac River from Cacapon Mountain.
(Photo from Pawpaw-Hancock Folio of U. S. Geological Survey).

The rivers represented the first highways and the towns were founded near the rivers, so that to-day we find the larger population in the valleys and the sparse settlements in the mountains. In this eastern Panhandle area, the larger cities and towns are in the Great Valley and along the Potomac. In the rich valleys beyond the mountains are small villages and large farms, while in the mountains are only scattered cabins and most of the area there is unsettled. The main roads of travel run north and south, or along the Potomac. The cross-mountain roads are but little travelled and many of them are almost impassable for vehicles. No railroad penetrates these mountains and they stand to-day for the memory of that old Virginia name of the country beyond the mountains—"The Wilderness."

CHAPTER III.

THE CLIMATE OF THE EASTERN PANHANDLE AREA.

GENERAL DESCRIPTION.

Weather refers to the condition of the atmosphere, and is dry or wet, cold or warm, cloudy or clear, etc. Climate, on the other hand, represents the average weather conditions over a period of months or years, and is described in similar terms to those of the weather, dry or wet climate, cold or warm climate. The present Chapter includes a discussion of the climate and climatic data of the eastern Panhandle Area, and it is based on the reports of the United States Weather Bureau.

Climate depends very largely on the latitude of the area. In the Tropics is a tropical, moist climate, while in the Polar regions is an arctic or frigid climate. The United States is in the North Temperate Zone where the climate is neither excessively hot nor extremely cold, though it may be a region of variable heat and cold in a comparatively short space of time, and thus has a changeable climate. The southern States have a milder climate than the more northern ones.

The climate of the eastern Panhandle Area is changeable and quite variable, but lacks the very low temperatures of the more northern States in winter, and the extreme and long-continued high temperatures of the more southern States in summer. Its nearness to the seacoast probably gives it a more moist and equable climate than the districts farther interior. The area has a range of altitude of nearly 2000 feet which will also affect the climate of its different portions. There will be lower temperatures recorded on the mountains than in the low valleys and the winter snows will probably be deeper there than in the valleys under average conditions.

These mountains and minor ridges will often act as barriers to storms and even cold and hot waves. They also by their obstruction insure changes in air currents and probably aid in the better circulation with resultant cool breezes in summer at night so that the nights are usually cool even after very hot days. Extreme low and high temperatures are exceptional. Below zero temperatures in winter and above 100 degrees in summer are very exceptional, and such recorded daily maximum and minimum temperatures through a long period of years can readily be counted in small numbers.

The area is therefore exceptionally favored in its average climate over many other districts. Frosts come earlier in the spring and later in the autumn, so that the growing season is of good length and fruit growing becomes a safer industry. The falls even after the first frost are usually clear and balmy with a long duration of Indian Summer, and low temperatures and snowy, stormy weather are usually not noted before December. The months of September and October with the tinge of frost in the air and the changing hues of the forests and the bracing yet balmy air are the most beautiful months of the year. Outdoor work conditions are usually favorable until well into December. As in other sections, exceptional conditions of weather will occur from time to time and an occasional late spring frost will wreak its damage on fruits and crops. A rare and unusual hailstorm will be recorded, but becomes prominent by its very rarity. Heavy snows of long duration on the ground in winter are very exceptional. Regions to the north and south will be under a heavy cloak of snow while this section shows the bare ground. The mean annual precipitation is high and there is an abundant rainfall for all growing crops, though in some years the rains may be unequally distributed with troublesome results in crops, a feature quite in keeping with other parts of the country. Heavy and destructive floods will come but again are exceptions and thus attract undue attention when they occur.

When other areas are in the grip of a long and severe cold wave, this district is favored by a short duration of the cold. Severe storms headed for this district are more often deflected to the east or west, leaving the area free from their havoc. Great sleet and wind storms pass along the coast or up the Ohio Valley, and this district knows of them only through the daily press.

Elevation above sea is an important climatic factor. The average elevation of the State of West Virginia is about 1,500 feet above sea-level, and it ranges from 260 at Harpers Ferry to 4,860 feet on Spruce Knob in Pendleton County. The average elevation of the eastern Panhandle is about 500 to 600 feet in the eastern portion, and probably 800 feet in the western part. By altitude the climate should be very similar to that of the Ohio Valley, but the climate seems to be much milder and its snowfall is less.

The mean annual temperature of the Ohio Valley is about 57 degrees at Wheeling, and 53.9 degrees at Parkersburg. At Morgantown, it is 52.8 degrees; at Grafton, 52.6; at Terra Alta, 49.5; at Point Pleasant, 56; and at Martinsburg, it is 52.7 degrees. The mean annual temperature of the whole State is 52.3 degrees. This temperature is quite uniform in the Great Valley north to Harrisburg, but is higher to the south. At Harrisburg, it is 52.9 degrees; at Clear Spring, Maryland, it is 52; and passing to the south to Staunton, Virginia, it is 54 degrees.

Comparing the rainfall of the State, the average is 42 inches. The rainfall yearly average at Morgantown is 44.56 inches; at Grafton, 44.8; at Point Pleasant, 42.9; at Parkersburg, 39.59; at Wheeling, 37.38; while at Martinsburg, it is 36.86, and 37.4 inches at Harpers Ferry. Going north in the Valley, the average yearly rainfall at Harrisburg is 34 inches. At Marion, Pennsylvania, it is 39.2 inches; and at Clear Spring, Maryland, it is 38 inches; and at Staunton, Virginia, it is 40.6 inches. The rainfall at Martinsburg thus appears to be about the same as at Wheeling, but less than to the north and south in the Valley, though greater than at Harrisburg.

The counties of Morgan, Berkeley, and Jefferson are located in the eastern Panhandle Area of West Virginia, within latitude of 39° 7′ and 39° 43′, and longitude 77° 45′ and 78° 30′. The length of the area along the southern border is 44 miles, its average width at right angles to the southern line is about 20 miles, and the area is 768.45 square miles. The elevation varies from 260 feet at Harpers Ferry, the lowest point in the State, to 2300 feet on Cacapon Mountain.

The United States Weather Bureau of Washington has been in existence over 40 years. Stations are maintained over the United States where trained observers are daily recording temperatures, rainfall, and other weather data, and these reports are published monthly, and annually, by States, with appropriate discussions of climatic and weather data. Daily weather predictions are issued which are posted in conspicuous places and published in the daily press, with storm warnings issued along the coast for protection of these coasts and shipping. Mistakes occur in these predictions from time to time, resulting in criticisms of the service, but the average predictions come very close to the actual results and great saving of life and property is the result. With the gradual accumulation of data and extensions of service and the added experience of the years, the service becomes more complete and more accurate. It is a great work filled with practical and scientific results.

In West Virginia, there is a central office at Parkersburg, with a Government Section Director (Mr. H. C. Howe) in charge. Volunteer observation stations are scattered over the State from which observations are daily made and sent to the central office at Parkersburg. This office then reports to the main office at Washington, and so on from the different States. There are 25 stations in the eastern and northern portions of the State and 19 in the southern part, or a total of 44 stations, with a number of others where rainfall only is measured, making a total in the State of 69 complete and incomplete data stations.

In the eastern Panhandle Area, there is only one complete data station, which is located at Martinsburg, where Mr. George W. VanMetre has made a complete series of records for the past twenty-five years. There is also a river observer at Harpers Ferry, S. W. Lightner, but only the rainfall is recorded for weather data. It would be of much interest if stations could have been maintained at Berkeley Springs. Charlestown, and Harpers Ferry.

In 1904 in the Annual Report of the Weather Bureau for the State of West Virginia, Mr. E. C. Vose, who was at that time Section Director, gave a general description of the climate of the State, which contains some very interesting data, a portion of which is here reprinted:

"The mean annual range of temperature over the State is from 6 to 8 degrees, the temperature being highest in the southwest portion and lowest over the mountains. The mean annual range of precipitation is from 15 to 20 inches, the precipitation being greatest over the mountains (due to the greatest amount of snow that falls there) and the least over the eastern Panhandle and extreme southern portions. The winter mean temperature of the western border, and the eastern Panhandle counties is from 31 to 34 degrees; the spring mean, 51 to 53 degrees; the summer mean is 74 degrees, and the fall mean is 55 degrees. The winter and spring precipitation averages about 10 inches; the summer, from 10 to 13 inches, and the fall from 7 to 8 inches. The extreme range of temperature is 142 degrees, the highest ever recorded being 107 degrees, and the lowest 35 degrees below zero. The average amount of sunshine for the State is about 50 per cent., and the prevailing direction of the wind is from south to west.

"The features of the weather that contribute to a successful crop growing season are numerous, but among them may be mentioned the following: sufficient rain in October and November to germinate wheat and rye, and to get them well stooled and rooted, and then ample snow protection during the winter; just enough rain in April to soften the soil so that plowing can be done; a May that is warm and pleasant, but with enough moisture to germinate the crops, and a summer season that has ample warmth and moisture.

"On the other hand, the features of a season that are unfavorable and that tend to the failure of the staple crops are drouth, accompanied by very hot weather in the fall, so that wheat, rye, and fall sown oats will not germinate; then sudden changes in the temperature during the winter, accompanied by frequent periods of hard freezing and thawing weather with but little snow on the ground, which condition tends to winter kill these grains; excessive rains in April and during the summer months, thus preventing the completion of plowing and sowing, badly washing growing crops and seriously damaging hay and grain during harvest; drouths in May and September especially, and also during the summer, these being accompanied by periods of extreme heat, thus drying up and withering the growing crops; abnormally low temperatures during June, July and August, which prevent rapid growth, and killing frost earlier and later than the average dates in May and September."

The different Weather Bureau Stations in the State are equipped with standard instruments for the taking of weather data, and include self-registering maximum and minimum thermometers, rain-gauge, and proper instrument shelter. Mr. Vose thus describes these instruments in the article above quoted:

"The maximum thermometer is always filled with mercury, sometimes called quicksilver. Its difference from an ordinary thermometer is that there is a constriction in the glass tube, just above the bulb, which prevents the mercury from going into the bulb when the temperature falls. When the temperature rises, however, the expansion forces the mercury through this stricture, and so it always shows the highest point reached for any time, or until set. This thermometer is set by whirling it vigorously.

"The minimum thermometer, as used by the Weather Bureau, is always filled with alcohol, and it is therefore easily distinguished from mercurial thermometers. Alcohol is used instead of mercury, because mercury congeals at about 40 degrees below zero, and in some places in the Dakotas and Montana a lower temperature than that even is reached. Besides the alcohol, there is also in the tube a little black object called the index, and this is the prime characteristic by which the thermometer is distinguished from all others. When the temperature of the air falls, the weight of the little steel index is so slight that the liquid contracting in the tube does not separate and leave the index up, but drags it back. When the temperature again rises, the expanding fluid passes freely by the index, and its upper end remains at the point of lowest temperature. The thermometer is set by raising the bulb end slightly so that the index may move gently to the top of the column. This thermometer can also be used as an ordinary thermometer as well as a minimum, as the current temperature is always recorded by the head of the alcoholic column.

"The rain-gauge consists of a galvanized can about three feet high and eight inches in diameter, on the top of which a receiver is placed to catch the rain and to carry it to the measuring tube. If the rainfall should be very heavy, and the tube be filled, the water will run over into the can, and then it can be measured by emptying into the tube, after that already in the tube has been measured. The diameter of the measuring tube is much smaller than the receiving tube, and rain in consequence fills the measuring tube to a much greater extent than the actual rainfall. In fact it is magnified just ten times. This is so as to make it easier to measure, as light rainfalls occur more frequently than heavy. The reading is always recorded in tenths just the same as it registers on the measuring stick.

"The purpose of taking temperature readings is to record the real temperature of free air, not, however, open to the sky and in the direct rays of the sun. In order to get the proper exposure, it is necessary to use a thermometer shelter. This is nothing more than a box with louvered sides made in such a way that the air can move through it with the greatest possible freedom. This is an essential condition in the thermometer exposure. The object of the box or shelter is simply to screen off the direct and reflected sunshine, and the radiation to and from the sky, and to keep the thermometers dry. The shelter is generally raised about four feet above the ground."

The following discussion of the weather and climate in the eastern Panhandle Area is based on the reports of the U. S. Weather Bureau as made at Martinsburg and the rainfall data as recorded at Harpers Ferry.

TEMPERATURE.

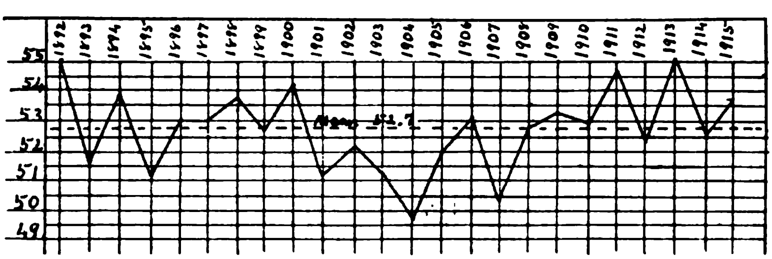
In Table I, the mean monthly and annual temperatures at Martinsburg are brought together, and a study of the table shows some very interesting facts. The lowest mean annual temperature was 49.7 degrees in 1904, which year also recorded the lowest mean at Parkersburg (52.3°). The mean annual temperature at Martinsburg for this long interval of observations is 52.7 degrees, and at Parkersburg, 53.9 degrees.

The coldest month in the year, according to these twenty-four year records, is February, with an average of 29.8 degrees. The coldest average monthly temperature recorded in this period of time was January, 1912, with an average of 21.6 degrees, and the highest average monthly temperature recorded was 78.2 degrees in July, 1911. The average winter mean temperature is 30.8°; spring, 51.9°; summer, 73.0°; and fall, 54.7°.

Table I.—Mean Monthly and Annual Temperature at Martinsburg for 24 Years.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1892	33.2	36.5	37.8	53.0	65.7	76.6	77.2	76.5	68.0	57.8	46.5	35.1	55.1
1893	23.4	31.8	40.4	51.5	60.2	71.0	74.6	72.2	64.0	52.9	39 6	37.2	51.6
1894	37.1	31.8	45.3	50.7	64.4	70.0	75.7	71.2	69.1	56.0	41.3	33.8	53.9
1895	26.4	22.8	39.5	52.1	61.0	72.2	70.7	74.0	69.0	49.2	43.7	35.2	51 3
1896	31.2	32.8	32.0	56.2	66.4	69.8	74.5	73.6	66.2	52.4	47.9	33.4	53.0
1897	28.7	34.6	43.4	50.6	60.4	68.4	76.1	71.5	66.9	56.9	42.8	36.1	53 0
1898	35.5	32.3	47.2	48.3	62.3	71.6	76.8	74.2	67.9	54.4	41 9	32.6	53.8
1899	30.9	28.5	39.5	52.8	63.3	72.4	74.9	73.2	64.6	54.8	43.4	34.6	52 8
1900	34.4	29.4	35.6	52.1	63.0	71.6	77.0	77.6	71.3	59.7	46.8	33.2	54.2
1901	31.4	26.6	41.2	48.3	61.2	70.1	78.0	73.5	63.6	52.9	37.6	29.8	51 2
1902	23.0	24.3	43.0	50.1	64.6	69.4	75.2	70.6	64.0	55.4	48.0	30.8	52.2
1903	29.2	32.4	47.5	49.3	63.0	65.2	73.5	69.8	64.2	54.1	38.3	28.2	51 2
1904	21.9	23.2	38.6	47.0	63.2	70.3	73.6	71 5	66.2	53.3	40.2	27.7	49.7
1905	28.0	22.8	42.6	51.8	64.7	70 6	75.4	73.2	65.0	54.2	41.0	34.5	52 0
1906	37.2	30.6	34.0	53.1	63.6	71.8	74.4	74.7	69.4	53.0	43.8	31.3	53.1
1907	32.8	24.1	44.7	45.2	57.2	65.5	74.0	70.2	66.0	50.6	40.6	33.4	50.4
1908	29.9	25.2	45.1	53.8	63.4	71.4	77.2	71 8	64.6	54.2	42.2	35.1	52.8
1909	31.7	39.7	39.7	51.1	61.8	72.1	76.5	71.8	66.2	49.9	47.9	29.8	53 2
1910	29.2	29.8	49.0	55.0	61.7	68.8	77.2	73.0	69.1	56.9	39.0	27.4	53.0
1911	34.8	34.8	38.6	49.6	69.9	72.8	78.2	75.2	68.3	55.0	40.9	38.2	54.7
1912	21.6	27.3	38.4	53.8	65.7	70.2	75.3	71.8	69.1	56.1	44.8	35.1	52.4
1913	38.4	33.2	46.0	54.2	63.5	73.0	75.8	73.4	64.6	55.8	45.2	37.8	55 1
1914	34.0	25.2	37.4	50.8	66.2	73.8	75.4	74 6	64.2	58.2	42.6	29.2	52.6
1915	31.9	35.5	37.6	58.0	60.9	70.2	76.0	72.3	69.2	56.6	43.4	32.6	53.7
1916	35.7	....	....	....	....	....	....	....	....	....	....	....	....
Average Mean Temperature ...	30.7	29.8	41.0	51.6	63.2	70.8	75.5	72.9	66.6	54.6	42.9	33.0	52.7

A graphic outline by means of a curve plotted according to range of temperatures and years gives to the eye a clear conception of the annual fluctuations of temperature. Figure 7 shows in this graphic form the variations in mean annual temperature at Martinsburg for a period of 24 years. The straight line represents the mean or average annual temperature for this period of years, and it is seen that the curve varies greatly from this line.



tinsburg for 24 years.
Figure 7. Diagram showing the Mean Annual Temperature at Mar-

Figure 8 shows in like manner the mean monthly temperature at Martinsburg for 24 years:

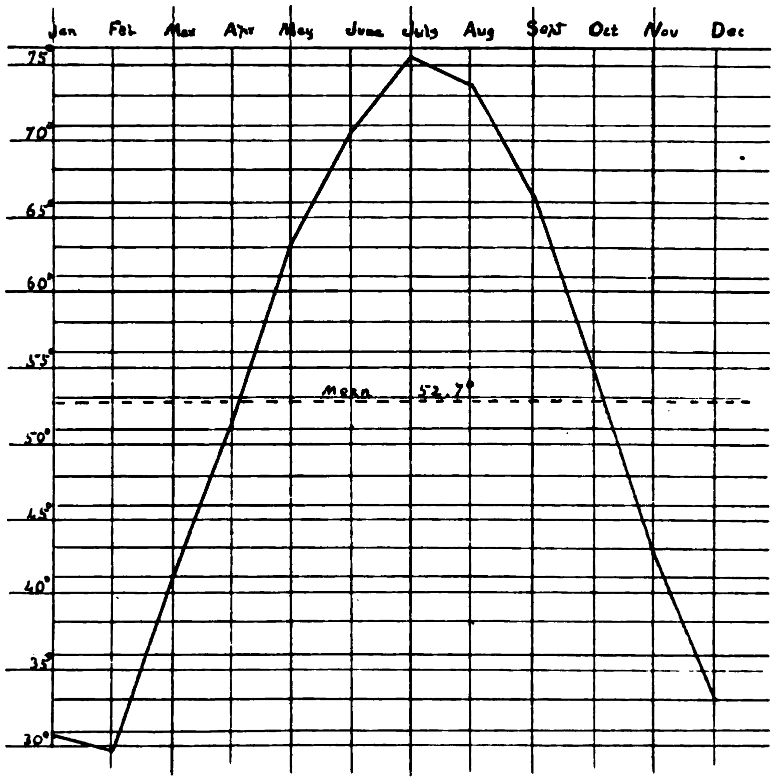


Figure 8. Diagram showing the Mean Monthly Temperature at Martinsburg for 24 years.

Tables II-A and II-B show the maximum and minimum recorded temperatures as taken by maximum and minimum thermometers at Martinsburg for twenty-four years. The highest temperature recorded on any day in this long period was 104 degrees in July, 1900. Recorded maximum temperatures of 100 degrees and over are rare in this area, and in the 24 years' records only twenty are found, and only eight passed 101 degrees. The maximum temperatures ranged from 100 to 104 degrees and were recorded in the following months: July, 1898; July and August, 1900; July, 1902; July, 1908; June and July, and August, 1911; July, 1912; July, 1913; July and August, 1914.

The lowest recorded temperature any day in the 24 years was 19 degrees below zero in January, 1912, and the next lowest was 12 below in January, 1904. Below zero temperatures are recorded in the months of December, January, and February. In December, below zero temperatures were recorded four years of the 24; in January, five years; in February, six years, so that very low temperatures in this area are exceptional.

Table II-A.—Maximum and Minimum Recorded Temperatures at Martinsburg for 24 Years.

Year.	January		Febr'y		March		April		May		June	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1892	57	8	54	-3.5	60	19	81	31	90	47	93	60
1893	56	-2	60	4	69	16	88	32	90	39	95	54
1894	65	14	56	3	81	18	81	24	86	39	95	42
1895	49	-2	58	-3	69	19	88	30	96	36	96	50
1896	60	5	60	3	70	-1	93	26	93	41	91	48
1897	63	3	55	11	75	20	89	26	83	40	90	41
1898	59	15	62	1	82	22	81	21	89	33	99	50
1899	56	5	55	-13	76	16	84	24	92	42	94	51
1900	62	9	57	3	66	2	79	28	94	35	93	50
1901	60	8	56	10	74	6	83	31	87	40	95	46
1902	54	7	56	0	76	15	91	30	93	38	98	44
1903	54	5	66	-6	76	22	86	22	90	31	86	46
1904	49	-12	63	-1	77	16	80	25	93	39	94	46
1905	64	-1	45	0	83	17	80	25	91	39	91	45
1906	70	8	60	4	62	16	86	27	94	34	96	50
1907	62	5	56	-10	90	14	82	19	88	32	92	44
1908	55	6	55	0	82	22	87	26	92	36	98	48
1909	62	3	68	15	59	23	86	21	91	33	94	52
1910	54	6	58	6	84	25	91	35	91	34	95	45
1911	69	12	66	18	75	10	82	21	98	36	101	53
1912	53	-19	57	3	71	16	83	28	94	37	94	42
1913	65	17	69	10	80	13	91	31	95	33	99	41
1914	62	4	50	0	77	13	84	25	97	38	99	46
1915	51	14	62	15	59	21	94	23	82	39	94	49
1916	72	3	....	....	....	....	....	....	....	....	....	....
Highest and Lowest Recorded Temperature	72 1916	-19 1912	69 1913	-13 1899	90 1907	-1 1896	94 1915	19 1907	98 1911	31 1903	101 1911	41 1897 1913

Table II-B.—Maximum and Minimum Recorded Temperatures at Martinsburg for 24 Years (Continued).

Year.	July		August		Septem r		October		Novem'r		Decem'r	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1892	98.5	58	95	63	85	51	81	37	70	26	65	11
1893	95	53	93	50	88	34	82	25	60	16	70	19
1894	98	50	93	51	93	42	84	33	68	20	52	20
1895	95	49	96	50	95	42	77	23	79	21	65	-2
1896	95	53	96	46	93	39	73	29	76	25	64	8
1897	95	56	92	54	98	36	90	31	71	20	69	9
1898	103	52	92	59	94	42	82	26	66	20	63	-1
1899	97	52	95	50	94	37	76	29	70	23	63	3
1900	104	52	100	54	95	40	85	31	75	21	57	10
1901	99	60	90	50	89	40	79	29	66	17	66	2
1902	102	53	90	47	95	37	80	27	75	22	54	9
1903	97	50	99	49	88	35	80	31	73	15	49	8
1904	97	49	95	45	93	34	89	25	67	18	51	-1
1905	96	55	92	49	87	38	86	28	67	18	56	10
1906	96	55	92	60	91	44	78	26	62	21	65	9
1907	93	50	92	50	89	39	78	24	62	21	63	12
1908	100	54	98	50	85	32	80	30	79	2	64	18
1909	96	50	98	49	83	40	77	27	76	26	57	6
1910	98	55	95	46	95	43	88	27	66	19	44	0
1911	102	54	102	51	89	42	83	32	69	18	67	19
1912	100	52	94	47	93	42	85	32	75	22	70	7
1913	102	53	99	51	94	31	76	24	74	25	63	20
1914	100	50	100	52	96	36	84	32	78	17	60	-4
1915	97	54	93	50	95	39	83	31	79	23	58	19
1916	....	....	....	....	....	....	....	....	....	....	....	...
Highest and Lowest Recorded Temperature	104 1900	49 1895 1904	102 1911	45 1904	98 1897	31 1913	90 1897	23 1895	79 1895 1908 1915	2 1908	70 1893 1912	-4 1914

The preceding two tables show the extremes of recorded daily temperature, while Tables III-A and III-B show the average maximum and minimum monthly temperatures for the twenty-four year period at Martinsburg. The highest average monthly maximum temperature was 92.4 degrees in July, 1911; and the coldest monthly temperature was 11.7 degrees in January, 1904. The average monthly range of temperature during this 24-year period was:

January 17.8	May 25.5	September ..24.7
February ...18.1	June 23.6	October 22.6
March 20.8	July 23.5	November ..21.2
April 24.3	August 23.2	December ...16.3

The variation in monthly temperature is seen to be the least in the month of December, and greatest in May.

Table III-A. — Monthly Average Maximum and Minimum Temperatures for 24½ Years at Martinsburg.

Year.	January		Febr'y		March		April		May		June	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1892	44	22.4	46	27	45.9	29.7	62	42	75.5	56	86.3	69
1893	32.1	14.1	41.3	22.7	50.6	30.3	62.7	40.6	72	49	81.5	60.5
1894	44.5	29.8	44.7	23	57.3	33.3	63.2	38.3	75	53	81	58
1895	35	16	33	13	50	29	64	40	73	50	84	60
1896	38	24	41	24.5	44.5	23	67	44	77.3	55	79.5	59.4
1897	37.2	20.1	42.1	28	54.6	32.1	64	37	72	48	79	56
1898	43	27	42	22	57	37	59	37	73	51	84	58
1899	39	22	31	15	48	31	66	39	75	51	83	62
1900	37	24	21	21	45	29	63	40	79	48	82	60
1901	40	23	35.2	18	51.7	30.8	57.6	39	72.8	49.6	82.6	57.6
1902	38.5	19.5	33.3	15.3	55.4	30.6	63.1	37.1	82.5	49.9	84.4	54.3
1903	37.4	21.7	43.7	21.1	58.3	36.7	60.7	37.9	78.1	47.9	75.8	54.5
1904	32.1	11.7	33.6	13	49.5	27.6	58.1	35.8	77.1	49.8	81.7	58.9
1905	36.6	19.2	31.8	13.9	54	31.3	65.8	37.8	77.9	51.5	82.1	59 2
1906	45.8	28.5	43.2	18.1	41.5	26.5	67	39.3	77.8	49.5	84	59.6
1907	42 4	23.1	34.6	13.6	56.6	32.8	57.7	32.8	69.9	44.5	77.2	53.8
1908	39.3	20.5	35	15.4	56.1	34.1	67.3	40.3	73.7	53.1	84.1	58.7
1909	40.4	23	50.2	29.2	49.6	29.8	62.8	39.3	74.6	49.1	83.2	61.1
1910	37.3	21.2	39.1	20.5	62	35.9	68	42.1	75.3	48.1	79.8	57.8
1911	44.0	25.7	43.2	26.5	49.8	27.5	61.4	37.9	85.3	54.5	85.8	59.9
1912	29.8	13.5	35.5	19.1	48.0	28.7	65.3	42.4	79.2	52.2	83.6	56.9
1913	58.6	28.2	42.9	23.6	57.4	34.5	66.1	42.4	76.8	50.2	86.1	59.8
1914	42.0	26.1	33.9	16.4	46.9	28.0	63.0	38.7	80.1	52.3	87.5	60.2
1915	39.6	24.2	44.3	26.7	47.7	27.4	72.7	43.2	72.4	49.4	82.4	57.9
1916	45.9	25.5	....	....	....	....	....	....	....	....	....	....
Average	39.98	22.2	38.4	20.3	51 5	30.7	63.6	39.3	76.0	50.5	82.5	58.9

Table III-B. — Monthly Average Maximum and Minimum Temperatures for 24½ Years at Martinsburg (Continued).

Year.	July		August		Septem'r		October		Novem'r		Decem'r	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1892	86.4	68	85	68	77	59	68.9	46.7	56.9	36.2	43.8	26.5
1893	90.5	62.3	83.6	61	74.4	53.6	63.8	41.8	49	30.3	46.7	27.8
1894	87	64	83	61	79	57	67	44	51	31	40	27
1895	82	59	87	61	85	53	64	35	54	33	43	24
1896	84.6	66.3	86	61.4	79.3	53.2	61	40.7	59	36	41.6	33.3
1897	80	65 5	84	59	82	51	68.6	45.5	53	27	43	29
1898	83	66	84	64	80	55	64	49	51	32	40	25
1899	86	63	85	61	77	51	68	43	53	33.9	44	25
1900	88	64	89	66	83	60	71	48	56	38	42	24
1901	88.5	67.5	84	63	75.9	51.2	67.3	38.5	47.9	27.4	39.5	20.1
1902	84.7	62.7	84.5	56.7	79	49	67.9	42.8	59.7	36.4	38.4	23.3

Year.	July Max	July Min	August Max	August Min	Septem'r Max	Septem'r Min	October Max	October Min	Novem'r Max	Novem'r Min	Decem'r Max	Decem'r Min
1903	87.1	60.5	80.5	59.1	77.8	50.6	42.6	42.6	50.4	26.1	37.6	18.8
1904	86.1	61.2	85	58	70	53.3	67.3	37	50.5	29.9	36.4	19
1905	88.5	64.5	84.3	62.2	77.5	52.6	67.2	39.5	52	29.9	43.6	25.4
1906	85.8	63.0	85.9	65.5	80.5	58 3	62.7	43.3	53.6	34	39.3	23.3
1907	86.7	61.4	82.8	57.5	76.8	55.3	65.8	35.3	49.8	31.3	42.8	24.1
1908	90.1	64.3	82.8	60.9	77.6	51.6	66 3	42.2	58.1	28.4	42.9	27.3
1909	92	61	84	59.7	79.9	52.5	62.3	38.6	59.9	36	37.3	22.4
1910	89.7	64.7	85.6	60.4	81.1	51.1	69.6	44.2	46.9	31 2	34.4	20.3
1911	92.4	64.1	86	64.3	78.9	57.7	64.4	45.5	50.2	31.6	46	30.4
1912	87.1	63.5	83.9	59.6	79.5	58.6	69.1	43.1	55.3	34.4	44.8	25.4
1913	88.4	63.2	85.9	60.9	77.2	51.9	64.5	47.0	55.3	35.2	46.1	29.4
1914	87.0	63.8	87.0	62.3	77.8	50.7	68.2	48.3	53.9	31.4	35.5	22.8
1915	88.4	63.7	82.6	62.0	81.4	57.1	68.2	45.0	54.7	32.1	40.0	25.2
1916	....	....	....	....	....	....	....	....	....	....	....	....
Average.	87.1	63.6	84.6	61.4	78.6	53.9	65.4	42 8	53.4	32.2	41.2	24.9

The details of Tables II and III are shown in graphic form in Figure 9:

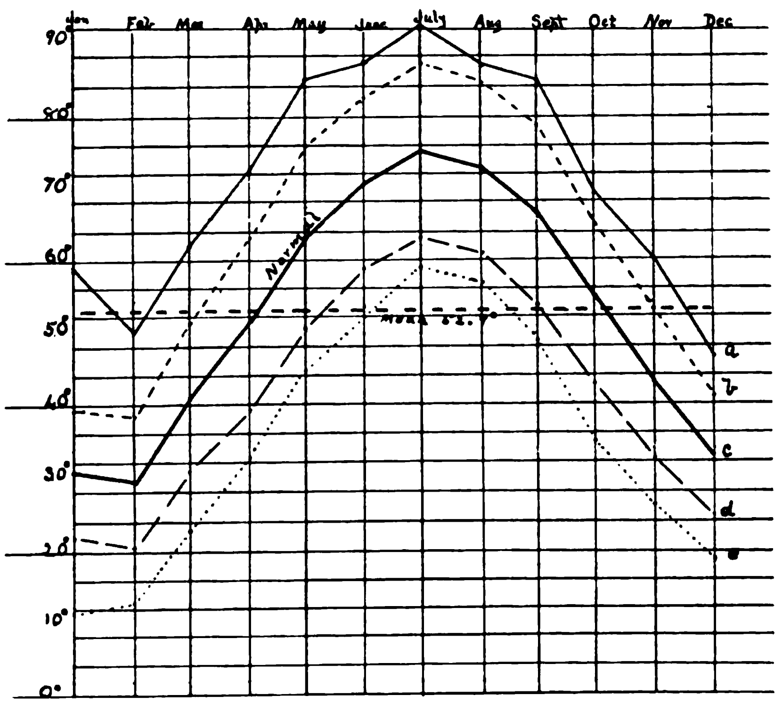


Figure 9. Diagram showing the Absolute and Average Maximum and Minimum Monthly Temperatures at Martinsburg for 24 years.

Table IV shows the number of hot days with a daily maximum temperature reaching above 89 degrees for the period of 24 years at Martinsburg, which gives an average of 30 hot days a year for this period. The least number of such hot days was 20, during the summers of 1893, 1903, and 1907, and the greatest number was 50 in 1911. The average in the mountains at Deer Park, Maryland, is four hot days. In this period of 24 years, there were only 20 days that recorded a temperature over 100°.

Table IV.—Number Hot Days with Maximum Recorded Temperature Over 89° at Martinsburg.

Year.	March	April	May	June	July	Aug.	Sept.	Oct.	Total
1892	....	....	4	8	11	7	....	....	30
1893	....	....	1	4	10	5	....	....	20
1894	....	....	....	5	13	2	2	....	22
1895	....	....	2	6	5	11	9	....	33
1896	....	3	3	1	5	10	4	....	26
1897	....	....	....	1	11	4	8	1	25
1898	....	....	....	7	13	5	4	....	29
1899	....	....	2	9	13	9	3	....	36
1900	....	....	5	5	15	16	7	....	48
1901	....	....	....	4	16	2	....	....	22
1902	....	2	2	6	13	3	3	....	29
1903	....	....	4	....	12	4	....	....	20
1904	....	....	3	8	8	6	3	....	28
1905	....	....	2	5	8	8	....	....	23
1906	....	....	3	6	6	4	2	....	21
1907	1	....	....	4	11	4	....	....	20
1908	....	....	3	8	17	9	....	....	37
1909	....	....	1	10	12	6	....	....	29
1910	....	1	1	7	16	8	1	....	34
1911	....	....	12	8	20	10	....	....	50
1912	....	....	4	4	13	6	8	....	35
1913	....	2	4	11	11	8	4	....	40
1914	....	....	6	12	12	11	4	....	45
1915	....	4	....	7	12	5	9	....	37
Average .	....	....	2.6	6	12	7	3	....	30

Table V shows the number of days with minimum recorded temperature below 32 degrees (freezing point) in the 24-year period at Martinsburg, an average of 111 cold days a year for this period. The least number of such cold days in the winter season was 81 in 1892, and the greatest number was 144 in 1904. Below zero temperatures were recorded 29 times in the twenty-four years, and 10 degrees or more below zero were recorded seven times.

Table V.—Number Days with Minimum Recorded Temperature Below 32° at Martinsburg.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	Total
1892	...	...	5	15	25	17	17	2	...	81
1893	...	2	16	20	30	23	17	...	...	108
1894	...	...	15	22	17	23	15	5	...	97
1895	...	9	13	23	29	28	22	6	...	130
1896	...	5	8	23	23	20	27	7	...	113
1897	...	1	12	18	26	21	16	7	...	101
1898	...	4	13	23	21	21	9	8	...	99
1899	...	4	11	21	26	22	13	10	...	107
1900	...	1	5	26	22	22	24	4	...	104
1901	...	2	20	27	26	27	15	1	...	118
1902	...	4	5	25	31	28	16	3	...	112
1903	...	2	21	30	23	21	8	3	2	110
1904	...	7	17	29	30	29	21	11	...	144
1905	...	4	20	22	27	28	15	3	...	119
1906	...	4	17	26	20	26	24	5	...	122
1907	...	8	15	25	21	28	16	14	...	127
1908	...	1	21	23	30	27	14	4	...	120
1909	...	5	9	27	23	17	21	3	...	105
1910	...	3	13	30	28	25	11	...	...	110
1911	...	...	17	18	22	23	21	4	...	107
1912	...	...	8	25	30	26	18	1	...	108
1913	2	3	10	19	21	24	15	3	...	95
1914	...	...	16	22	25	26	22	6	...	117
1915	...	1	15	27	26	20	24	6	...	119
1916	...	...	...	...	18	...	...	...	...	...
Average	...	3	13	24	25	24	17	5	...	111

EARLY AND LATE FROSTS.

In Table VI, the dates for the latest frost in the spring and the earliest frost in the fall are given for 24 years at Martinsburg.

PLATE VII(A).—Purslane Sandstone on Sideling Hill, Morgan County.

PLATE VII(B).—Rockwell Sandstone and Shales on Sideling Hill.

Table VI.—Killing Frosts at Martinsburg.

Year.	Last in Spring.	First in Autumn.	No. Days Between.
1892	April 12	Nov. 21	222
1893	April 16	Oct. 17	183
1894	April 11	Nov. 7	209
1895	April 20	Oct. 10	172
1896	April 10	Oct. 9	181
1897	April 22	Oct. 31	191
1898	April 9	Oct. 20	193
1899	April 17	Oct. 1	166
1900	April 15	Oct. 18	185
1901	April 6	Oct. 26	202
1902	April 15	Oct. 22	189
1903	May 3	Oct. 25	175
1904	April 23	Oct. 7	166
1905	April 19	Oct. 22	185
1906	April 8	Oct. 12	186
1907	May 12	Oct. 12	153
1908	April 17	Sept. 30	165
1909	April 12	Oct. 20	190
1910	March 20	Oct. 29	222
1911	April 10	Oct. 29	201
1912	April 8	Oct. 17	191
1913	May 12	Sept. 23	135
1914	April 11	Oct. 27	198
1915	April 16	Oct. 11	1[illegible]
Average			185

The average number of days between frosts is seen to be 185. At Parkersburg, the average is 178; at Wheeling, 197; at New Cumberland, 164. In the Valley District in the past few years, the average number of days between frosts is 160 at Marion, Pennsylvania; 189 at Clear Spring, Maryland; and 161 at Staunton, Virginia. There is thus a good length of safe growing season in this Valley and especially so in the Martinsburg district.

SNOWFALL.

Table VII shows the monthly and annual snowfall at Martinsburg for the past twenty-four years. The greatest amount was 46.3 inches in 1907, and the least was 2.7 inches in 1901. The average amount of snowfall was 27.2 inches at Martinsburg. At Morgantown, the average is 30.2 inches; at Grafton, 39.5; at Rowlesburg, 52.8; at Point Pleasant, 17.5; at

Wheeling, 29.1; at Parkersburg, 22.7 inches. The monthly averages show the greatest amount of snowfall at Martinsburg in February with 9.2 inches.

Table VII.—Monthly and Annual Snowfall (Inches) at Martinsburg.

Year.	Nov.	Dec.	Jan.	Feb.	March	April	Annual
1892	2.5	1.5	7.5	12.5	12.0	0.0	36.0
1893	2.0	0.0	9.5	21.5	4.0	0.0	37.0
1894	0.0	9.0	1.0	17.5	0.0	2.0	29.5
1895	T	3.0	10.5	13.0	0.5	0.0	27.0
1896	0.0	2.0	0.0	1.5	20.5	0.0	24.0
1897	2.0	2.0	5.0	12.5	1.5	0.0	23.0
1898	5.0	7.0	2.0	0.0	3.0	2.0	19.0
1899	0.0	0.0	4.0	29.0	2.0	T	35.0
1900	0.0	0.0	1.0	12.0	18.5	0.0	31.5
1901	0.2	T	2.5	T	T	0.0	2.7
1902	T	7.0	10.0	4.0	20.0	0.0	41.0
1903	0.5	1.0	5.0	6.0	T	0.0	12.5
1904	0.0	20.0	13.0	1.0	T	0.0	34.0
1905	T	7.3	13.0	7.0	0.0	T	27.3
1906	0.0	0.0	2.5	5.0	14.0	0.0	21.5
1907	0.0	6.5	13.5	17.0	9.0	0.3	46.3
1908	8.0	5.5	5.0	19.5	T	0.0	38.0
1909	0.0	6.0	11.0	0.5	3.5	0.0	21.0
1910	T	13.5	20.0	7.0	1.0	0.0	41.5
1911	0.0	T	4.0	9.5	7.0	T	20.5
1912	0.0	8.0	15.0	1.0	4.5	0.0	28.5
1913	0.0	1.0	2.0	3.0	T	0.0	6.0
1914	0.0	8.0	T	22.0	8.0	0.0	38.0
1915	0.0	2.0	5.0	T	5.5	0.0	12.5
1916	....	....	0.0	....	....	....	....
Average	0.8	4.6	6.7	9.2	5.6	0.2	27.2

RAINFALL.

Rainfall in some seacoast areas may reach 50 to 60 inches a year, and in the arid regions of the far West may fall as low as 20 inches. In the Tropics, 80 inches have been recorded. Under average Temperate Zone conditions, the rainfall averages around 35 to 40 inches a year.

Table VIII shows the monthly and annual precipitation cr rainfall at Martinsburg for twenty-four years, with the monthly and annual averages for that period. The month of greatest rainfall was August, 1911, with 10 inches, and the least was March, 1910, with 0.17 inch. The greatest annual rainfall was 50.36 inches in 1901, and the least was 28.98 inches in 1895.

The average annual rainfall at Martinsburg based on these records is 37.1 inches. The average at Morgantown is 44.56 inches; at Point Pleasant, 42.9 inches; at Wheeling, 37.38 inches; at Parkersburg, 39.6 inches. The average rainfall in winter months is 7.69 inches; in spring months, 9.81 inches; in summer months, 12.03 inches; and in fall months, 7.57 inches.

Table VIII.—Monthly and Annual Rainfall at Martinsburg.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1892	3.81	1.35	5.15	3.14	2.42	3.51	2.50	1.40	1.43	0.21	2.06	2.49	29.46
1893	1.96	2.64	1.32	4.28	5.22	1.83	5.95	3.50	2.81	4.75	2.98	0.87	38.11
1894	0.87	2.52	1.26	2.97	9.40	2.85	2.21	1.11	2.42	3.85	1.02	3.18	33.66
1895	2.45	1.29	2.25	3.93	3.26	3.07	2.78	2.25	1.77	1.38	1.50	3.05	28.98
1896	1.60	2.97	2.58	1.30	1.26	7.54	5.64	1.03	3.50	1.13	2.48	0.75	31.78
1897	1.05	4.90	2.53	2.20	5.00	3.18	2.85	2.78	1.80	1.15	4.70	3 10	35.24
1898	3.15	1.29	3.35	1.87	4.51	1.42	3.20	7.00	1.31	5.09	2.91	3.50	38.60
1899	2.05	4.35	4.15	1.30	5.15	3.32	1.15	3.01	3.48	1.95	2.15	1.70	33.76
1900	1.76	4.54	2.95	1.60	0.35	3.63	3.52	2.60	3.80	1.15	3.00	1.75	30.65
1901	1.65	0.25	3.08	6.75	8.35	5.69	5.60	7.37	2.10	0.55	3.72	5.25	50.36
1902	3.25	3.20	5.75	3.72	1.56	3.22	4 52	2.16	2.60	4.55	3.55	3.25	41.33
1903	2.95	3.15	3.35	4.55	3.90	5.40	5.90	4.05	2.17	2.63	0.85	1.25	40.15
1904	2.05	1.05	2.18	2.58	5.48	4.60	5.61	1.65	4.00	2.45	1.05	2.35	35.05
1905	3.70	0.85	2.95	1.52	1.90	6.05	9.30	3.25	1.90	3.35	1.85	2.98	39.60
1906	2.60	1.20	4.25	2.35	1.00	7.00	3 50	9.50	0.70	4.30	0.85	3.90	41.15
1907	3.00	1.90	3.90	3.32	3.75	5.37	5.41	4.50	6.25	1.30	3.88	3.60	46.18
1908	1.00	2.80	3.10	1.60	5.25	2.69	3.24	4.70	1.88	1.73	0.80	1.12	29.91
1909	1.96	3.58	2.76	3.64	3.64	3.57	1.37	2.89	3.65	2.64	0.78	2.83	33.29
1910	3.41	2.79	0.17	3.96	2.29	5.66	4.55	1.06	0.92	1.76	1.05	1.45	29.07
1911	3.74	1.30	2.27	3.01	1.48	3.93	2.44	10.00	4.02	3.27	2.20	3 95	41.61
1912	1.65	2.67	6.10	2.49	4.11	6.33	4.86	2.10	7.93	0.70	1.89	3.75	44.58
1913	2.13	1.10	6.66	2.51	3.98	2.10	2.81	2.43	2.89	6.89	3.04	3 05	39.59
1914	3.98	3.15	2.18	4.31	2.22	3.34	2.42	4.58	0.82	2.20	2.27	3.03	34.50
1915	4.96	4.32	0.82	0.93	4.95	5.84	3.20	8.36	2.49	3.16	1.29	3.21	43.53
1916	2.05	....	....	....	....	....	....	.....	....	....	....	....	.....
Average .... Rainfall	2.53	2.46	3.13	2.91	3.77	4.21	3.94	3.88	2.78	2.59	2.20	2.70	37.1

Table IX shows the monthly and annual rainfall at Harpers Ferry, 19 miles east of Martinsburg. This series of records extends over a period of 26 years. The greatest monthly rainfall was 9.18 inches in September, 1912; and the least was 0.00 inches in October, 1892. The greatest amount of annual rainfall was 54.75 inches in 1901, and the least was 27.41 inches in 1910.

Table IX.—Monthly and Annual Rainfall at Harpers Ferry.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1889	....	....	....	....	....	....	3.27	1.36	5.94	3.87	5.29	0.35	.....
1890	0.50	3.09	2.87	2.40	4.56	2.15	2.32	5.54	3.97	5.35	0.69	3.16	36.60
1891	2.01	2.09	5.52	1.64	2.38	3.40	5.08	3.48	0.38	1.55	1.97	2.33	31.83
1892	3.90	1.30	5.15	2.65	3.06	5.56	1.89	2.01	3.31	0.00	3.50	1.60	33.93
1893	1.37	2 20	0.62	4.08	4.57	2.28	2.84	3.36	2.17	4.95	1.89	0.32	30.65
1894	0.78	3.33	1.11	3.39	7.85	3.13	1.56	0.65	2.70	3.00	0.51	2.31	30.32
1895	4.33	1.40	1.43	2.83	4.67	4.35	2.00	2.12	1.18	0.16	2.50	2.83	29.80
1896	1.94	4.19	2.48	1.64	4.60	5.25	5.08	0.88	4.29	0.88	2.06	1.04	34.33
1897	1.44	5.76	3.12	2.14	5.67	3.20	4.12	4.50	1.57	2.27	5.56	3.90	43.25
1898	4.15	1.49	4.36	1.87	6.51	1.08	2.12	5.64	1.47	8.50	3.60	3.69	44.48
1899	3.25	4.80	4.48	1.06	3.96	2.51	2.76	5.69	3.97	1.51	3.06	2.88	39.93
1900	2.43	4.68	3.56	1.62	2.41	3.58	4.61	2.29	2.48	1.38	3.62	2.32	34.98
1901	2.25	0.51	5.27	7.96	7.81	3.44	4.85	5.00	6.40	0.60	3.70	6.96	54.75
1902	3.20	2.20	6.14	2.10	1.50	2.00	5.60	0.60	1.95	5.54	2.91	5.45	39.16
1903	3.41	3.45	5.24	4.95	2.52	5.08	4 87	4.82	2.23	3.27	0.79	0.69	41.32
1904	2.21	1.42	2.29	2.25	3.44	5.95	4.92	1.47	2.33	1.55	1.31	2.58	31.72
1905	4.89	2.18	2.42	1.49	1.86	6.03	5.46	4.17	2.88	2.87	0.78	3.76	38.79
1906	2.51	1.58	3.27	3.26	1.75	4.68	4.86	6.74	0.57	8.15	0.35	3.19	40.91
1907	3.05	2.54	2.26	4.54	3.20	5.61	1.99	3.70	4.91	0.54	4.28	2.60	39.22
1908	3.77	3.77	1.23	1.13	6.11	2.60	3.04	5.03	1.74	2.90	0.84	1.06	33.22
1909	2.16	3.22	2.33	3.86	2.92	4.31	0.60	3.54	1.84	1.70	0.63	2.62	29.73
1910	3.73	2.41	0.86	5.30	1.81	5.30	1.27	0.90	0.99	1.71	1.04	2.12	27.41
1911	3.73	1.32	1.84	2.96	0.58	3.93	3.53	8.98	3.28	3.28	1.93	2.61	37.97
1912	2.01	1.26	4.91	2.48	3.29	1.11	4.88	4.27	9.18	0.42	2.50	3.51	39.82
1913	2.33	0.77	4.61	2.04	3.27	1.14	2.19	3.78	1.44	6.06	2.67	2.56	32.86
1914	4.01	2.18	1.89	4.57	2.48	4.03	1.28	4.68	0.86	1.75	2.15	3.69	33.57
1915	5.26	4.00	1.01	0.76	4.35	5.21	1.87	8.32	2.12	3.74	1.45	3.06	41.15
1916	1.70	....	....	....	....	....	....	....	....	....	....	....	.....
Average Rainfall	2.87	2.58	3.09	2.88	3.74	3.73	3.29	3.83	2.82	2.83	2.28	2.70	36.6

In Figures 10, 11, 12, and 13, the data in Tables VIII and IX are shown in graphic form.

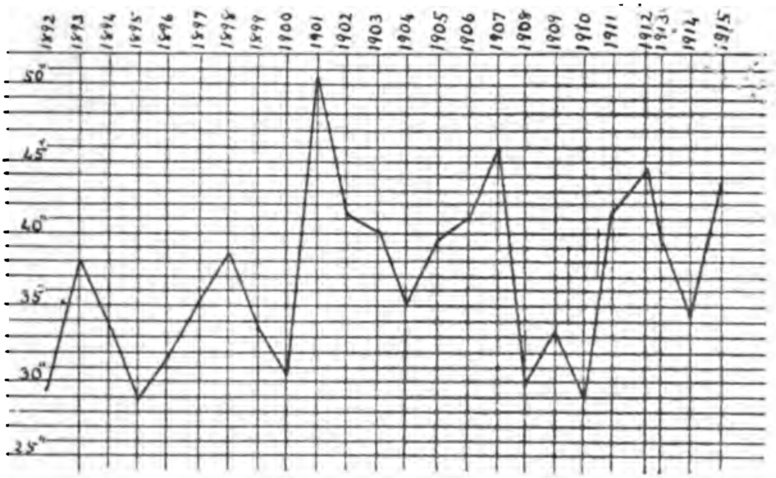


Figure 10. Diagram showing the Variation in Mean Annual Rainfall at Martinsburg for 24 years.

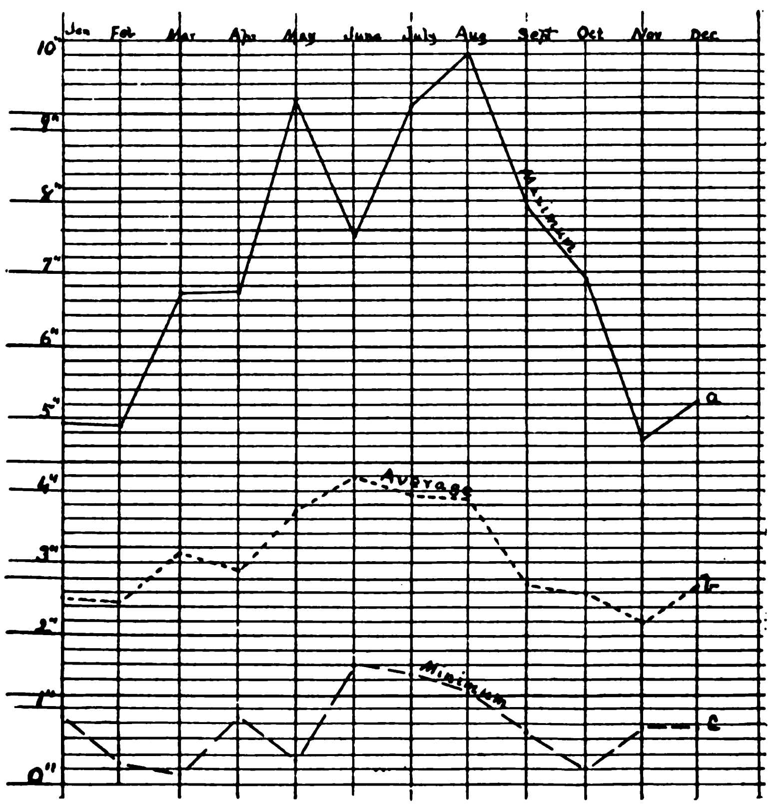


Figure 11. Diagram showing the Monthly Mean, Minimum, and Maximum Rainfall at Martinsburg for 24 years.

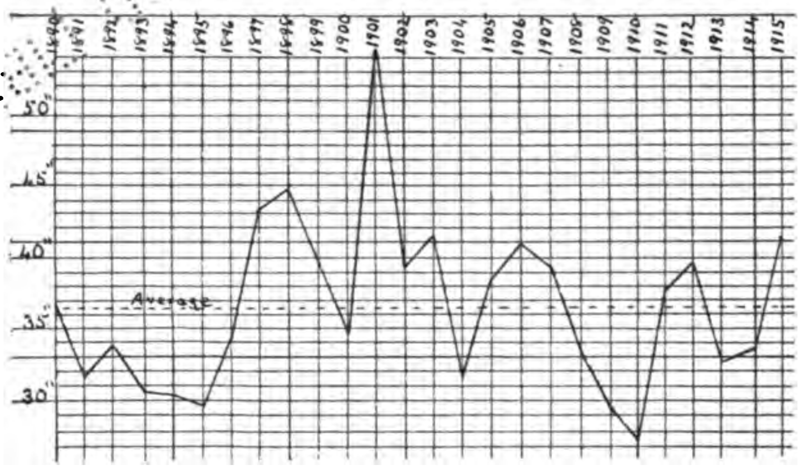


Figure 12. Diagram showing the Variation in Mean Annual Rainfall at Harpers Ferry for 26 years.

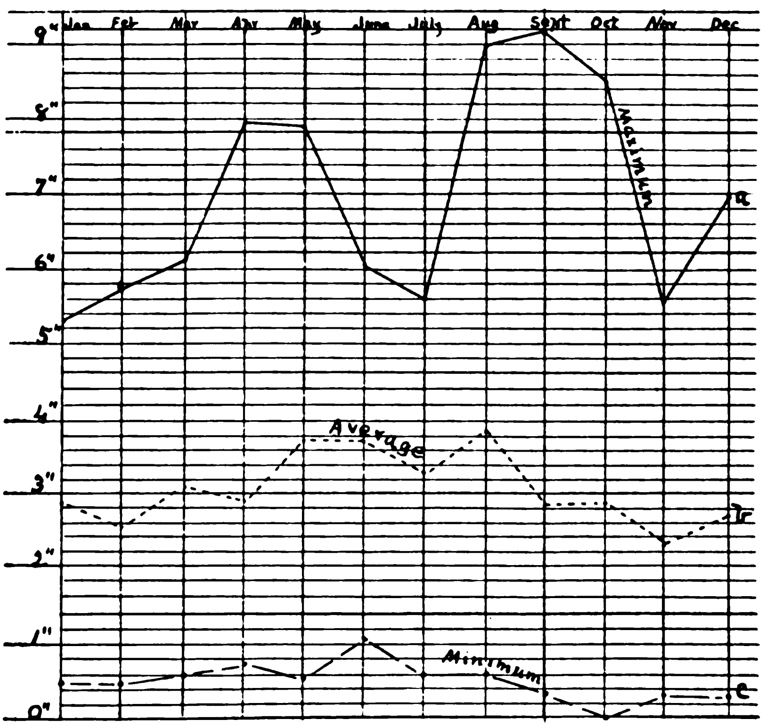


Figure 13. Diagram showing the Monthly Mean, Minimum, and Maximum Rainfall at Harpers Ferry for 26 years.

In the period of 24 years at Martinsburg, the average annual rainfall exceeded 40 inches in seven years; and in the 26 years at Harpers Ferry, six years showed an annual rainfall over 40 inches. The month of August showed the highest average rainfall at both places, 3.8 inches; and November was the month of least rainfall, with 2.2 inches.

FAIR, CLOUDY, AND RAINY DAYS.

Tables X-A and X-B show the number of fair, cloudy, and rainy days at Martinsburg during the past twenty-four years. In these records, the observer marked as rainy days those in which most of the day was rainy, while days with local showers, or showers of short duration were classed with cloudy days, and days with no rain were called fair days.

Table X-A.—Fair, Cloudy, and Rainy Days at Martinsburg. (Snow included with rain).

Year.	Jan.			Feb.			Mar.			Apr.			May			June		
	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy
1892	10	12	9	6	16	7	9	9	13	9	15	6	9	11	11	15	6	9
1893	9	16	6	9	7	12	10	12	9	9	10	11	14	5	12	11	9	10
1894	11	12	8	10	5	13	15	11	5	16	5	9	12	2	17	20	..	10
1895	11	7	13	13	8	7	12	10	9	13	10	7	10	9	12	15	2	13
1896	10	18	3	11	6	12	11	9	11	13	8	9	9	10	12	12	6	12
1897	12	12	7	10	7	11	10	8	13	14	7	9	13	4	14	12	6	12
1898	10	9	12	17	8	3	8	7	16	13	7	10	9	6	16	19	4	7
1899	16	7	8	7	10	11	8	11	12	17	10	3	12	6	13	11	14	5
1900	13	12	6	11	6	11	8	15	8	16	6	8	15	13	3	11	10	9
1901	12	16	3	19	8	1	13	11	7	13	12	5	12	8	11	11	10	9
1902	17	10	4	13	11	4	16	8	7	14	13	3	15	8	8	18	2	10
1903	14	11	6	14	9	5	13	11	7	15	10	5	19	6	6	9	11	10
1904	15	12	4	14	12	3	10	15	6	14	9	7	18	5	8	15	7	8
1905	13	9	9	13	11	4	12	12	7	12	11	7	17	6	8	17	5	8
1906	12	12	7	20	2	6	10	13	8	17	9	4	18	11	2	12	3	15
1907	9	10	12	12	11	5	18	7	6	12	10	8	13	9	9	15	6	9
1908	16	10	5	13	9	7	13	9	9	21	1	8	16	6	9	21	3	6
1909	14	8	9	12	8	8	18	3	10	16	6	8	19	5	7	14	1	15
1910	11	9	11	16	6	6	22	7	2	12	8	10	15	8	8	10	11	9
1911	16	5	10	13	10	5	15	8	8	10	12	8	25	1	5	14	3	13
1912	15	8	8	19	6	4	13	6	12	13	4	13	18	3	10	14	5	11
1913	12	14	5	19	5	4	12	9	10	12	7	11	16	5	10	19	2	9
1914	15	8	8	15	5	8	13	10	8	16	5	9	24	1	6	21	1	8
1915	16	3	12	14	3	11	22	5	4	19	9	2	16	9	6	15	11	4
1916	18	5	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Table X-B.—Fair, Cloudy, and Rainy Days at Martinsburg (Continued). (Snow included with rain).

Year.	July			August			Sept.			Oct.			Nov.			Dec.		
	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy	Fair	Cloudy	Rainy
1892	13	11	7	12	15	4	18	6	6	15	15	1	10	13	7	7	19	5
1893	20	3	8	19	1	11	14	8	8	18	7	6	15	8	7	13	12	6
1894	17	6	8	12	14	5	7	9	14	14	11	6	12	14	4	14	7	10
1895	14	10	7	18	4	9	17	9	4	23	3	5	11	12	7	10	15	6
1896	12	4	15	20	3	8	16	4	10	8	16	7	16	5	9	14	13	4
1897	12	9	10	20	1	10	24	3	3	12	13	6	13	6	11	10	10	11
1898	16	9	6	13	9	9	22	3	5	12	5	14	13	8	9	13	11	7
1899	12	11	8	14	5	12	18	4	8	16	11	4	13	11	6	15	10	6
1900	18	4	9	19	4	8	16	8	6	18	9	4	7	14	9	18	8	5
1901	13	8	10	18	4	9	18	5	7	21	8	2	13	13	4	17	8	6
1902	16	7	8	21	2	8	15	9	6	17	8	6	18	6	6	13	10	8
1903	19	0	12	12	9	10	24	3	3	17	10	4	18	7	6	22	6	3
1904	13	5	13	16	7	8	17	6	7	23	5	3	17	11	2	12	14	5
1905	15	3	13	17	8	6	24	2	4	21	6	4	16	9	5	15	11	5
1906	17	6	8	8	7	16	17	11	2	12	11	8	19	7	4	8	15	8
1907	20	0	11	17	6	8	15	6	9	22	6	3	14	9	7	11	12	8
1908	21	0	10	15	9	7	18	10	2	21	6	4	23	6	1	13	13	5
1909	21	4	6	19	6	6	19	7	4	22	5	4	18	6	6	16	12	3
1910	19	5	7	18	8	5	20	4	6	24	1	6	11	15	4	16	12	3
1911	21	3	6	15	3	13	17	5	8	17	4	10	16	8	6	14	10	7
1912	19	1	11	16	9	5	14	6	10	21	6	3	20	6	4	14	8	9
1913	20	0	11	18	9	4	20	5	5	16	3	12	16	5	9	15	10	6
1914	19	2	10	17	4	10	24	1	5	16	5	10	23	3	4	10	6	15
1915	9	18	4	9	17	5	20	7	3	17	5	9	20	6	4	13	11	7
1916	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

The average conditions of sunshine and rainy days as obtained from these tables for the 24 years are shown in Table XI, and illustrated by the graphic diagram in Figure 14:

Table XI.—Average Weather Conditions at Martinsburg for 24 Years.

	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Fair	13	13	13	14	15	15	17	16	18	18	15	13	180
Cloudy	10	8	9	8	7	6	5	6	6	7	9	11	92
Rainy	8	7	9	8	9	9	9	9	6	6	6	7	93

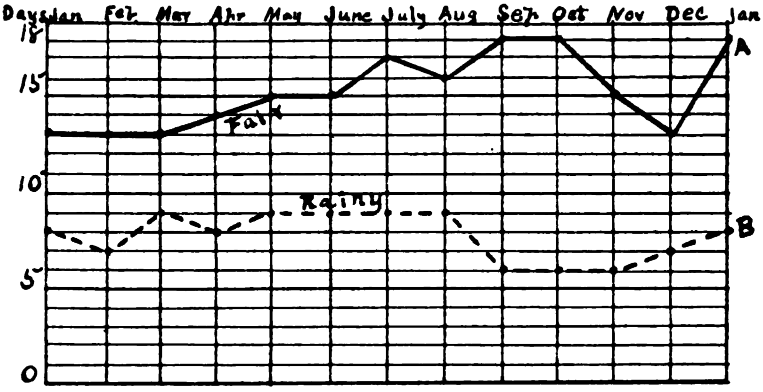


Figure 14. Diagram showing the Average Number of Fair and Rainy Days at Martinsburg for 24 years.

This table shows that at Martinsburg there are annually an average of 180 clear days, and 185 cloudy and rainy days. The average at Wheeling for 29 years is 199 clear days and 166 cloudy and rainy days.

WIND DIRECTION.

The prevailing direction of the winds at Martinsburg is from the northwest; though in the summer, the winds are mostly south. The wind direction varies in this area and is sometimes southeast, southwest, northwest, etc.

In the records for twenty-four years at Martinsburg, the following prevailing directions of wind were recorded by years in the different months to January, 1916:

	Northwest.	West.	North.	Southeast.	South.	Southwest.	Northeast.
January	14	3	6	..	..	1	..
February	20	1	2	1	..	..	..
March	15	2	1	4	2	..	..
April	17	2	2	..	3	..	..
May	6	3	..	5	10	..	..
June	11	..	2	..	11	..	..
July	9	..	..	..	12	2	1
August	9	..	2	3	9	1	..
September	14	..	..	3	5	1	1
October	18	..	2	1	3	..	..
November	18	4	1	..	1	..	..
December	17	4	2	..	1	..	..

PART II.

The Geology of the Eastern Panhandle Counties.

CHAPTER IV.

GENERAL GEOLOGY AND STRUCTURE OF THE EASTERN PANHANDLE AREA.

GEOLOGICAL DEFINITIONS.

GEOLOGY is one of the branches of science which treats of the history of the earth in its progress as a planetary body to its present condition. It is therefore a very comprehensive science including nearly all the work done in and on this globe on which we live. Its object is to decipher the complete life history of the earth, and no other science equals it in arousing mankind from the old fixed idea of the unchangeableness of the earth, **terra firma**, as it is called, yet it is in reality almost a type of instability. Geology teaches us that the organic law of adjustment to environment applies not only to the organic world, but equally so to the inorganic, and that even the everlasting hills and the great rivers are only transitory features on this earth. Geology has rendered two great services to mankind; first, the enlargement of the intellectual realm and vision for man; and second, the development of the economic resources, adding thereby to the wealth and comfort of man and nations.

Since the time of Newton, it has been known that the shape of the earth is spheroidal, but it was early believed that the interior was molten with a solidified surface crust. While now it is believed that the earth is practically solid, the old term survives, and it is customary to speak of the crust of the earth, referring to that portion of the surface which can be studied either on the surface or at shallow depths in mines or drillings, or at greater depths through volcanic energy and the materials thereby ejected. This crust of the earth is composed of rocks which according to their origin are classified into three groups: Igneous, Metamorphic, and Sedimentary. The first group includes the granites, syenites, volcanic rocks, etc., but it is only sparingly represented in West Virginia, and may therefore be ignored in this discussion. Metamorphic rocks are those which have been changed by great heat and pressure in the crustal movements of the earth and have so lost their original characters. They may have been igneous or sedimentary rocks originally, but they are now greatly altered or metamorphosed. Limestone is thus changed to marble, sandstone to quartzite, shales to roofing slate, coal to anthracite, carbonaceous material to the diamond or graphite, etc. Examples of this group may be found in the mountain regions of the State.

Most of the rocks of this State belong in the third group of Sedimentary Rocks, that is, they have been deposited as sediments under water, later consolidated by mechanical or chemical processes into solid strata. Sand has been consolidated into sandstone, lime mud into limestone, mud into shales, etc. The presence, therefore, of large deposits of sedimentary rocks is proof that at some past time that area was under water. In this water often flourished life, animal or vegetable or both, and the remains of this life are often preserved in the rocks as fossils.

Sedimentary rocks are stratified, separating along more or less parallel planes into layers or strata, and these may further break into plates or laminæ. They represent consolidated sediments, the particles being held together by some cementing substance as, lime carbonate, silica, iron oxide, or alumina, or they have been rendered solid by long-continued pressure.

In some cases the parallel bedding is broken by cross-lamination or **cross-bedding**, representing not folding, but an angular deposition of material due to rapid currents in the old ocean, and it is thus characteristic of shallow-water conditions. There will also be found in the shallow water sediments, ripple-marks, worm-burrows and trails, seaweed impressions, rain-drop prints, sun-cracks, and the like. All these characters when found in sedimentary rocks attest their shallow-water origin.

Structural Geology treats of the kinds of rocks, their arrangement and position. The most important group of rocks in the eastern Panhandle Area, as well as in the entire area of the State, is the Sedimentary. They were originally deposited in nearly horizontal beds, and they often carry the evidences of their water origin in ripple-marks, worm and seaweed impressions, and they also contain fossils. They were deposited under the waters of the sea or other bodies of water. As a corollary to this evidence, the hills, mountains, and valleys of this area, composed of these rocks, were at one time under the waters of the ocean or its tributaries where the sediments that compose the rocks were deposited.

The so-called horizontal rocks are not truly so, but have a slight dip or slope, which is greatly increased in the tilted rocks. The **dip** of a stratum is defined as its inclination to the horizontal plane, and it is expressed in degrees and direction. It may vary from 0 degrees in horizontal rocks to 90 degrees in vertical ones. The line of intersection of the dipping plane with the horizontal is called the **strike**, and its direction is always at right angles to that of the dip. The line along which the dipping bed cuts the surface of the ground is the **outcrop** of the bed which line by erosion will bend down in hollows and rise over hills. The determination of the thickness of horizontal beds is readily made by simple measurement, but in dipping strata more or less covered by debris and with angle of dip, the measurement becomes a more difficult problem. In the measurement of such beds along the outcrop, the thickness of the stratum would be computed by a simple formula. The thickness of the stratum would equal the horizontal length of outcrop multiplied by the sine of the angle of dip. The angle of dip is measured by a dial instrument with a movable arm which may be set in the direction of the dipping plane, and the angle of dip is measured on a graduated quadrant on the instrument. This instrument is called a **clinometer.** The direction of the dip is read by a compass.

Sedimentary rocks by earth movements may become highly inclined or even thrown into folds. There are three types of folds; the Anticline, the Syncline, and the Monocline. **Anticlines** are upward folds in which the strata dip away from the central line or axis on the crest of the fold, similar to the roof of a house. **Synclines** are downward folds in which the strata dip toward the central axis in the bottom of the trough, or the opposite condition to the anticline. In the normal order the anticline would form a ridge, and the syncline would form a valley, but by erosion, the order may be reversed and result in anticlinal valleys and synclinal ridges or mountains. The axes of the folds dip or pitch and finally disappear, and the fold is said to die out in a given direction. A **Monocline** is a simple bend or fold connecting a higher and lower level of the strata, the parts so connected may be horizontal. These folds may be symmetrical when they dip each way from the axis in equal degree; or one side of the fold may have a steeper dip than the other and the fold is unsymmetrical. One of the classic fields for the study of mountain folds in the world is the Appalachian area, and illustrations of these folds are to be found in text books of all languages.

The cause of such folds is lateral pressure due probably to the shrinkage in the cooling of the earth. The process was very slow and continued through a long course of time. The rocks so folded now occupy much less space than the original horizontal layers. They have been crowded together and thrust upward. In the laboratory of the United States Geological Survey, experiments have been carried on with artificial pressure on loaded strata of wax of different degrees of hardness in the separate layers, and the slowly applied lateral pressure produced folds and other structures in miniature that almost duplicated the natural structures of the Appalachian Mountain range, an experimental proof of the theory of lateral pressure in producing these results.

When the strata are formed under the same sedimentary conditions in a continuous manner, there is no break between the strata and they are said to be conformable and a **Conformity** exists. Strata again may be deposited and then raised into a land area, then depressed and a new order of strata laid down on the eroded surface of the first series. Under such conditions sedimentation has not been continuous and a break occurs between the old and the new, representing a time interval whose duration and record are lost and this is called an **Unconformity.** In the history of the earth, an unconformity means that the leaves of the history at this place are lost. Such a condition is found at the close of the coal formation in this country and there is a marked unconformity between the old life periods of the Paleozoic time and the newer life records of the Mesozoic.

Stratified rocks may often be readily broken apart along the parallel planes of sedimentation, but they also break along other planes more or less parallel which are known as **Joints.** These planes may be due to shrinkage in the consolidation of the sediments into rocks, or to strains set up in the rocks by crustal movements. They are often at right angles to the bedding-planes and may be at right angles to each other in two sets, or again may run at various angles. They are of aid in the quarrying of stone and they will determine the size of the blocks so quarried.

When the joint-plane extends through many layers, they are called **fissures** and they may be of large extent in length and depth. They may be filled with mineral matter and thus become mineral veins, in many localities even carrying ores and become of economic importance, as the fissure ore veins of the West. Where the fissure in the rock shows one side of the wall higher than the other, it is termed a **Fault.** The extent of this vertical displacement may be a few inches or less, or again may run into thousands of feet. Usually one wall of the fault overhangs the other, and the upper one is called the hanging wall, and the lower, the foot-wall. Usually the plane of fracture of a fault is inclined or dips forming the hanging and foot-walls. **Normal faults**, as they are called, incline or dip to the downthrow side, and the angle of the fault and the amount of the displacement are readily determined by measurement. In mountain areas examples are common where the upper side of the fracture or fault appears thrown up over the lower side along a thrust-plane and a **reverse fault** results, often called a thrust-fault. Such faults are due to lateral pressure as in case of the folds. The pressure may form the fold and continue in force until the top of the fold breaks and one side is thrust over the other. Examples of this type of fault may be seen in the North Mountain and Third Hill Mountain in the area under discussion in this Report. Along fault-planes the rocks are sometimes striated and polished, forming **slickenside** surfaces on the rocks.

Sedimentary rocks were formed under water, as has been shown above, and later were raised into dry land with gently dipping horizontal beds in the normal order. But the succession of the rocks with their different fossil life characters shows that these rocks were again and again depressed below the sea and reelevated, resulting in the orderly sequence of rock strata as found to-day. With the emergence of such a land area from the sea, three great geological processes began their work: Erosion, Transportation, and Deformation.

EROSION.—By erosion the new land area is worn down to sea-level by the atmospheric agencies of rain, snow, sun, frost, etc., and by the work of the rivers and the sea. The mechanical and chemical effects of the elements of the air result in the destruction of the rocks and therefore of the land area. In course of time, comparatively short, the hard resistant granites crumble to sand under the onslaught of the elements, as may be seen in a few years' history in railroad cuts through these rocks. The action is continuous day and night, year in and year out, and results in the pile of loose debris around every rock exposure. This process is called **weathering**, and soils and clays have their origin in this process. While a portion of the results of rock decay can be seen in the debris left behind, a considerable portion of it is removed in streams, and a very considerable portion passes away invisible in solu tion into the runs and rivers and finally to the sea.

TRANSPORTATION.—The mechanical and chemical products of the disintegration of the rocks are carried seaward by running waters. Much of the material is carried by the rivers in suspension visible in the muddy, turbid water, not so apparent, but still present also in the clearer streams. A greater amount is pushed along the river floor by the action of the current, as well as the materials in chemical solution which give to waters their chemical composition in the mineral or medicinal springs. All of these conditions represent the transportation work of the stream. In more quiet reaches of the river, portions of the transported material may be deposited, while other parts are carried to the sea and there deposited as river sediments in delta or shore deposits. The river is a great agent of transportation, and it is also a great agent of erosion through this material which it carries. A stream without sediment does not erode its channel, but the detritus carried by it acts as so many engraving tools in sculpturing its valley and eventually destroying it. The valley was not made for the river, but was made by it. This subject is more fully discussed in the Chapter on Physiography.

DEFORMATION.—The rocks as raised from the sea by the earth's changes would be horizontal or nearly so in the normal uplift, and this is the present position of the sedimentary rocks in undisturbed areas, as illustrated by the Carboniferous strata over the western portion of this State, but even in these rocks there are found minor crumplings and deviations from the horizontal position into low anticlines, synclines, and monoclines, which have given to the world the great accumulations of oil and gas in those economic fields.

The rocks in the eastern portion of the State are much more disturbed from their original position than at the west. These changes in form and position of the rocks are included under the term **Deformation.** The forces of deformation may be vertical by direct upheaval of the rocks, or horizontal by lateral movements of the earth. By the first, the land is raised to higher levels; by the second, the rocks are crowded together and thrown into folds which may extend to a considerable

PLATE VIII.—View looking up Meadow Branch Run, Purslane Sandstone Boulders in Bed of Stream.

height above sea-level. Most mountains have been formed in this way. The great Appalachian belt was so formed in the first place, but the present mountains of this belt are due to direct vertical uplift at a later period after the original crumpled range was eroded to a sea plain and then reelevated, and carved out by erosion.

CLASSIFICATION OF THE SEDIMENTARY ROCKS.

The rocks of the earth's surface have been classified by geologists in a series of historical divisions based for the most part on the life of past ages as preserved in a fossil state in these rocks. It is found that this life differed in different rocks, but in the same stratum as followed from place to place there was a similarity in the life. Further there was a progressive order in this life from the older period to the next younger. It was thus found that the rocks could be arranged in this order and traced to different parts of the country and even over the world. The main divisions of the geological column so constructed on these life characters are as follows:

Cenozoic—Recent life forms.
Mesozoic—Less recent life forms.
Paleozoic—Oldest forms of life.
Algonkian
Archaean—Crystalline rocks with no undisputed evidence of life.

The basal portion of this column includes the crystalline rocks, as the granites, syenites, diorites, etc., and is not represented to any extent in West Virginia, though they are found just on the boundary in the Blue Ridge. In the gravel terraces there is a representative of the uppermost division, the Cenozoic. Most of the geology of this State is included in the Paleozoic and in one division of this era, the Carboniferous; though the eastern portion and the area under discussion; namely, Morgan, Berkeley, and Jefferson Counties, is included in the column from the Lower Carboniferous down to the base of the Paleozoic. The subdivisions of this Paleozoic era are as follows:

Carboniferous { Permian or Permo-Carboniferous (Upper). Pennsylvanian (Middle) Mississippian (Lower).

Devonian.
Silurian.
Ordovician.
Cambrian.

COLUMNAR SECTION.

GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE EASTERN PANHANDLE AREA.

	Symbol.	Section	Thickness. Feet.	Formation.
CARBONIFEROUS	Pk		115	Pinkerton Sandstone.
	My		850	Myers Shale.
	He		180	Hedges Shale.
	Pu		250	Purslane Sandstone.
	Ro		600	Rockwell Formation.
DEVONIAN	Ct		3200	Catskill Formation.
	Ch		2115	Chemung Shales.
	Po		1765	Portage.
	Ha		1200	Hamilton Shale.
	Ma		330	Marcellus-Onondaga.
	Or		225	Oriskany Sandstone.
	Hl		300	Helderberg Limestone.
SILURIAN	Bo.		350	Bossardville Limestone } Salina Formation
	RwB		450	Rondout Waterlime and Bloomsburg Red Shales & Ss's } Salina Formation
	Na		170	Niagara Formation.
	Cl		550	Clinton Shale.
	Md		200	White Medina.

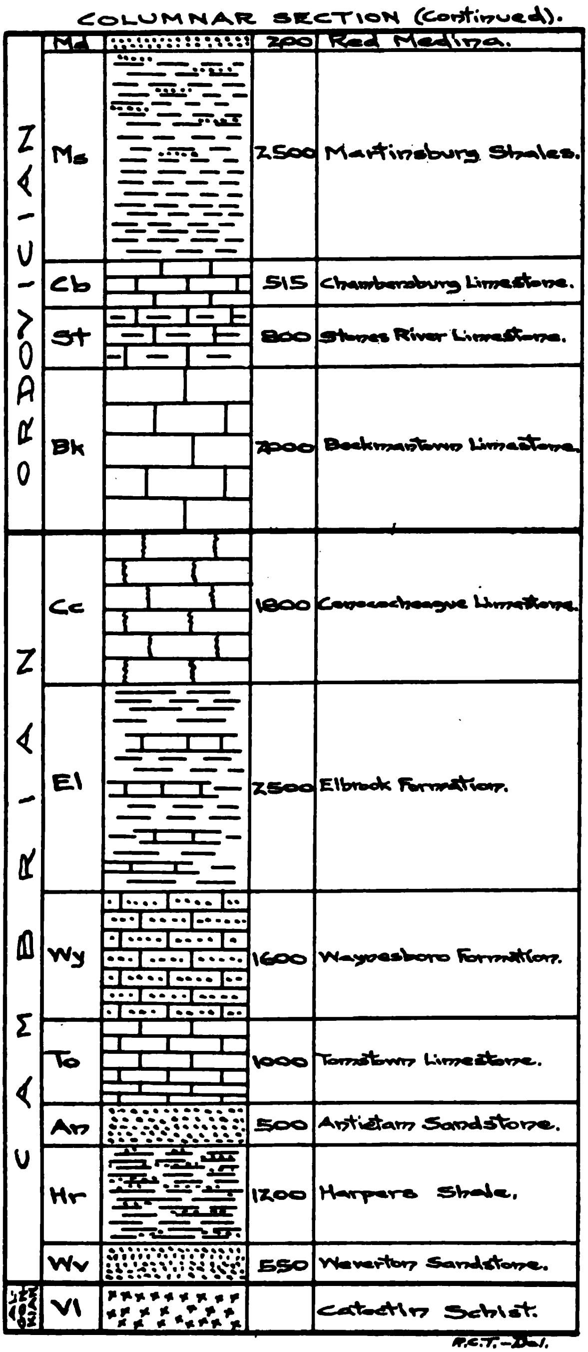

COLUMNAR SECTION (Continued).
ORDOVICIAN
CAMBRIAN
Md
200
Red Medina.
Ms
2500
Martinsburg Shales.
Cb
515
Chambersburg Limestone.
St
800
Stones River Limestone.
Bk
2000
Beekmantown Limestone.
Cc
1800
Conococheague Limestone.
El
2500
Elbrook Formation.
Wy
1600
Waynesboro Formation.
To
1000
Tomstown Limestone.
An
500
Antietam Sandstone.
Hr
1200
Harpers Shale.
Wv
550
Weverton Sandstone.
Vl
Catoctin Schist.
R.C.T.-Del.

Figure 15.

CLASSIFICATION OF THE EASTERN PANHANDLE FORMATIONS.

The rocks of the eastern Panhandle Area belong in the Mississippian, Devonian, Silurian, Ordovician, and Cambrian. These subdivisions of the Paleozoic are further subdivided into the following groups:

MISSISSIPPIAN.

Mauch Chunk Red Shales.
Greenbrier Limestone.
Pocono Sandstone.

DEVONIAN.

Catskill Formation.
- Chemung.
- Portage.
- Genesee.
- Hamilton.
- Marcellus.
- Onondaga.

Oriskany Sandstone.
Helderberg Limestone.

SILURIAN.

Salina Formation.
- Bossardville Limestone.
- Rondout Waterlime.
- Bloomsburg Red Shale.

Niagara (McKenzie Formation).
Clinton.
Medina.
- White Sandstone.
- Red Sandstone.

ORDOVICIAN.

Martinsburg Shales.
Chambersburg Limestone.
Stones River Limestone.
Beekmantown Limestone.

CAMBRIAN.

Upper or Saratogan.
- Conococheague Limestone.

Middle or Acadian.
- Elbrook Formation.
- Waynesboro Formation.

Lower or Georgian.
- Tomstown Limestone.
- Antietam Sandstone.
- Harpers Shale.
- Weverton Sandstone.

ALGONKIAN.

Catoctin Schist.

GEOLOGICAL STRUCTURE OF THE EASTERN PANHANDLE AREA.

The Appalachian Mountain region is one of intense folding and faulting where the rocks have been crowded together in close unsymmetrical folds with a general northeast-southwest trend at high angles of dip and often overthrust with reversed dips. The structure is further complicated by the larger folds being thrown into minor folds and these into lesser folds, one on top of the other. The complexity of structure increases from west to east.

The eastern Panhandle Area is located in this Appalachian belt of rock disturbance. In the western part of the area are well-defined fairly smooth folds, with a fair degree of symmetry and but few overthrusts, while in the Meadow Branch Mountain area and North Mountain, the folds are overthrust, more so in North Mountain than to the west and with the addition of large faults, and in the limestone valley eastward, the folds are sharp, close together, with numerous fault-planes and overthrust faults, the structure becoming especially complicated near the Blue Ridge.

The Appalachian folds dip down and die out when followed north or south, and while some are described with a length of 50 miles, most of them are much less. As one disappears, another comes in, so that the folded structure extends the length of the mountains.

Along the line of the Appalachian Mountains, the strata have been estimated to be about 40,000 feet thick, while the same strata in the Mississippi Valley, according to LeConte, are about 4,000 feet thick, so that sediments during Paleozoic time accumulated in great thickness along this eastern line. The strata are mostly those formed in shallow water or within twenty to fifty miles of a coast-line, and they are characterized by ripple-marks, cross-bedding, and other evidence of shallow water origin, and yet have accumulated in this great thickness. The deposits must have been accumulated in a slowly sinking trough which thereby formed a line of weakness in the earth's crust. The rocks were deposited as horizontal sediments, for the same strata traced westward become practically horizontal. The folding of these horizontal sediments has been so great that according to Willis, 100 miles of lateral extent of sediments are now concentrated into a width of 65 miles. The folding of these rocks was probably due to a slow and long continued force or series of forces acting through Paleozoic time reaching a culmination near the close of that era, because the Carboniferous rocks are involved in the folding while the Triassic rocks east of the Blue Ridge are not much altered or folded. The folding then took place before the Trias and in part after the Carboniferous. It does not seem reasonable that the forces causing folding came all at once at the close of the Paleozoic as formerly so often stated to be the case. It is far more reasonable to suppose, as Willis pointed out, that through the divisions of Paleozoic time these forces were at work and changes were taking place in this accumulating mass of sediments in the sinking trough. The effects may have been slight during a large portion of the time, accentuated at certain intervals, as at the close of the Silurian and at the close of the Devonian, and finally the rocks showing well developed lines of weakness, initial folds were probably started so that the major amount of folding came at the close of the era and the mountains were then greatly uplifted, a period of time often described as the "Appalachian Revolution".

The forces which caused the original mountain elevation and folding were due to the readjustments of the cooling globe in past ages whereby strains and stresses were set up resulting in the yielding of the surface portions along lines of weakness, and the sinking trough of the Appalachians formed such a line of weakness. These stresses were possibly set up by the adjustment of the cooler surface crust to a shrinking interior mass, or possibly to the sinking of old ocean basins with a cotemporaneous rising of continental masses by the theory of isostacy, a theory of continental equilibrium first advanced by Dutton, but soon thrown aside as an improbable hypothesis, and more recently resurrected as furnishing a very probable hypothesis for many continental histories and origin problems. The sinking ocean basin would cause at great depths below a landward sliding of softened sediments under the vast pressure involved and the resistant surface land areas would oppose rising so that there would be a crumpling of the strata, swelling them into mountain folds. Which of the two theories is the true explanation of the cause of folding, it is impossible to state and very possibly both have been effective. Observations multiplied over and over, and actual mechanical experiments on layers of material of different textures and rigidity under applied pressures in the laboratory appear to have established the fact that the rock folds and faults have been formed by horizontal forces or lateral pressure applied at right angles to the direction of the fold axes. In the Appalachians, the axes of the folds are northeast-southwest, so the direction of the deforming forces was from the northwest or from the southeast. The facts observed throughout the mountain area, as first pointed out by the Rogers Brothers; namely, the direction of the overturns and of the thrust-faults being to the northwest, the folding, faulting, and alteration of the rocks under pressure increasing from west to east being greatest in the Blue Ridge, all indicate that the forces came from the southeast. There would be various local stresses set up which would run in different directions causing some minor changes in direction of the overturns and the folds, but these were probably secondary to the main action.

With the rock folding and faulting there would be various rock alterations and a greater or less degree of metamorphism. If the heat and pressure were sufficient, there would be a complete alteration of the rocks. Limestones would become marble, sandstone would form quartzite, shales would form roofing slate, coal would become anthracite. In the eastern Panhandle area, these effects are seen, but not always complete. What coal is found is in the form of anthracite or at least semi-anthracite. A number of the sandstones are quartzites, and some of the shales approach roofing slates in character, but the change was not complete. The limestones are not changed into marble, but they are rendered more crystalline and brittle in texture and in some cases approach closely to marble in character. Slaty cleavage so characteristic of these alterations is found imperfectly developed in the shales or slates and to some extent in the rocks of the more prominent folded overlying shales are found on the upper mountain slopes. The inner portion of the two ridges dipping toward the run valley are on the dip slopes of the fold, with dips around 50 degrees, but steeper to the east than to the west. The outer slopes of the ridges are due to the erosion of the sandstones and shales. The slope is more gradual to the east than to the west. On the eastern limb, the fold is in places overturned with an eastern dip. On the western limb, the syncline is broken by a minor anticlinal fold which extends from the transverse valley of Rockwell Run southward. At the north the syncline is cut through by the Potomac, exposing Mississippian rocks on both sides of the river down to the water-level which is nearly 1,200 feet below the even crest of the mountain, and near the river the two ridges converge, forming an open syncline on Sideling Hill, extending north across the river through Maryland. Southward the fold is capped by the hard Purslane Sandstone to about opposite Pawpaw, while the underlying Carboniferous shale and sandstone extend about one mile further south.

A minor syncline between the Sideling Hill and Pawpaw folds incloses also Mississippian rocks, forming the crest of Spring Gap Mountain at the Hampshire County Line, about one and a half miles southeast of Pawpaw. This fold is lost to the northward in the soft Catskill Shales.

CACAPON MOUNTAIN ANTICLINE.—At Cacapon Mountain, the rocks are raised into a well-defined anticlinal fold which is slightly a-symmetrical. The western dips are greater than the eastern by about 10 to 15 degrees. The mountain is capped over most of its extent by the hard Medina White Sandstone which forms high cliffs with very picturesque scenery as at Prospect Rock and other points. The view from its summits reveals a panorama of ridges and valleys over a horizon of many miles. The distant level topped Sideling Hill and the various lower peneplains with a gorge of the Potomac and windings of the Cacapon are wonderfully clear. This is the highest mountain in the area, gradually rising from the Potomac near Sir Johns Run southward until it reaches a height of 2,300 feet above tide.

In portions of the ridge, the Clinton Shales and Sandstones have been preserved in narrow outcrops, but most of the crest and upper slopes are composed of hard White Medina Quartzose Sandstone. The fold dips to the north and disappears north of the Potomac. On the western upper slope in deep ravines, erosion has revealed patches of the underlying Red Medina Sandstone, while on the lower slopes the Clinton and upper members of the Silurian are exposed and often greatly crumpled by minor folding. A series of these crumpled minor folds are well exposed in the Keefer Sandstone member of the McKenzie Formation at the Fluted Rocks on Cacapon River southeast of Great Cacapon Station. Here is a series of close anticlines crowded together and standing out in bold relief. This sandstone is thrown into similar fluted folds at several places to the south along the mountain to near Rock Ford, but they are more concealed by debris and vegetation.

On the western limb of this anticline, the outcrop of resistant Oriskany Sandstone has preserved the ridge of Tonoloway, which slopes gradually westward from a height of 1100 to 1200 feet, and slopes steeply to the Cacapon River on the east. Much of this eastern side of the ridge is nearly a vertical wall of limestone capped with the Oriskany Sandstone. This erosion ridge extends across Morgan County, forming the west bank of the Cacapon River, which cuts across the ridge at Ziler Ford, and the ridge is also cut by the deep narrow Potomac gorge at the north.

The rocks of this ridge dip westward 60 to 75 degrees and the western slope is formed of the Marcellus and Hamilton Shales, while on the east are exposed the upturned edges of the Helderberg and Bossardville Limestones to the river, whose valley is excavated in Silurian Shales. From Tonoloway Ridge west to Sideling Hill is the broad syncline of Catskill and Portage and Chemung Shales with minor erosion ridges capped with the more resistant included sandstones.

East of Cacapon Mountain is the Silurian Valley of Sir Johns Run to the Warm Spring Ridge, which is another Oriskany Sandstone ridge, corresponding to Tonoloway on the western limb of the anticline. The western slope of this ridge is composed of the Helderberg and Bossardville Limestones underlain by the Silurian Shales of the valley, while the eastern side is formed of Oriskany Sandstone, with the Devonian Shales on the lower slope. The eastern dip of the sandstone near Berkeley Springs is about 50 degrees, but further south decreases to 40 and 35 degrees, thus showing the less eastern slope of the anticline as compared with the greater western slope at Tonoloway. The height of the two ridges is about the same, 1000 to 1100 feet on Warm Spring Ridge.

If the outcrop of the strata be plotted along the lines of their dip until those on the two ridges of Tonoloway and Warm Spring meet, they would represent a mountain mass 5,500 feet high at the summit, which would give some idea of the amount of erosion that has taken place in the area through the ages gone by.

East of Warm Spring Ridge is a broad, rather shallow syncline in the Devonian Shales which contains at the north a minor anticline, bringing in an outcrop of the Catskill rocks near the Potomac. There is also a minor anticline in the Parkhead Sandstone at the north which broadens to the south and becomes obscure in the shales, but is indicated by the position of the outcrops of the Parkhead Sandstone south nearly to Stotlers Crossroads. In the southern part of the county near Oakland and Ungers Store, a small anticline brings the Catskill red rocks to the surface.

MEADOW BRANCH SYNCLINE.—In the Meadow Branch area to the east of Sleepy Creek is a broad synclinal fold in the Catskill Shales and Sandstones, which, like the Sideling Hill fold, incloses Mississippian strata that in a similar way, by their resistance to erosion, have resulted in the formation of two mountain ridges—Sleepy Creek Mountain on the west, and Third Hill Mountain on the east—separated by the Mississippian shale valley of Meadow Branch. It is in the valley shales that the anthracite coal is found, and this coal-bearing shale is brought up on the rising eastern limb of the fold to near the top of Third Hill Mountain.

Sleepy Creek Mountain is capped by the hard Purslane Sandstone which also forms its inner eastern slope and also the slope of the western limb of the syncline. The sandstone extends down this slope almost to the valley floor, with an eastern dip of 30 to 40 degrees. The upper western slope of the mountain is composed of the softer sandstones and shales of the Rockwell division of the Mississippian, while the Catskill Red Shales extend well up the slope. The soft character of these shales and sandstones has resulted in rapid erosion, giving a very rough western slope, cut by deep narrow ravines and gullies, while the eastern mountain slope has a smoother outline but is covered with masses of sandstone boulders.

The inner or western slope of Third Hill Mountain is composed of the red and buff shales with ledges of sandstone of the Mississippian, and with dips of 30 to 40 degrees, so that the fold is nearly symmetrical, much more so than the other folds of the region. The top of the mountain is composed of hard sandstone and conglomerates, while the upper eastern slope is composed of the shales and lower sandstones which over much of the mountain are overturned to the west so that the dip is apparently east at high angle, reaching 70 to 75 degrees. As these overturned strata are followed southward, the overturn passes into a minor anticlinal fold in the Purslane Sandstone, which, east of the Myers place, includes a small fold of the coal-bearing shale on top of the mountain. This minor fold seems to start near Pinkerton Knob and was not seen north of that point.

The eastern slope of this mountain is quite steep and covered with the Purslane boulder debris nearly down to the valley, concealing the underlying rocks to a large extent. Minor folds on the main syncline are seen at a number of places along the inner slope of the mountain on the eastern limb of the syncline above the Meadow Branch Valley, but could not be traced for any distance on account of lack of clear rock exposures.

This synclinal structure with the overturn north of Pinkerton Knob brings the coal outcrop near the creek valley level and again near the top of the Third Hill Mountain. The slopes of the coal seams in the valley are 30 to 45 degrees east, while near the top of the mountain the seams are nearly vertical. Borings in the vertical portions have in the past been interpreted as giving the thickness of the seam and reached in some reports 50 to 60 feet of supposed thickness of seams. Other borings were made on the eastern slope beyond the coal shales and naturally failed to reach any coal. The failure to work out the structure in advance of this early drilling resulted in a considerable waste of labor and money. The details of the structure show that the coal does not pass through Third Hill Mountain as was supposed formerly by prospectors to be the case. Many of the valley prospect holes are shafts through the overlying Myers Red Shales to the Hedges Coal Shale below, so that a map of coal holes does not represent the outcrop of the coal shales, which is quite narrow in the valley and more so near the top of the mountain.

The hard sandstone of the Mississippian disappears north about four miles south of the Potomac River and the mountains there also die out, but the syncline is preserved in the red shales of the Catskill to the river and for some distance into Maryland. It is well marked by the mountains south past the Virginia Line. The center of the fold is east of Meadow Branch Run and at the Potomac is to the east of Sleepy Creek Station.

Sleepy Creek Mountain reaches an elevation of 1800 feet; Third Hill, 1700 feet, while Meadow Branch Valley is 800 feet at the lower end and 1160 feet at the Myers place. At the north end near Devils Nose, Third Hill Mountain ends in Paines Knob, while an eastern spur, known as Short Mountain, is separated from Sleepy Creek by the Meadow Branch gorge.

East of Third Hill Mountain, the syncline continues in the Catskill Shales, with a minor anticline followed by a short syncline to the anticlinal fold of Ferrel Ridge. The minor anticline is not well defined in the Devonian Shales to the south, but north, near the river, about one mile west of Cherry Run Station, it brings up the Helderberg and Oriskany in a narrow outcrop, flanked on both sides by the Marcellus-Hamilton Shales. This Lower Devonian outcrop extends for about a half mile south of the river and with about the same width on the river, but to the north in Maryland widens out into a broad belt.

FERREL RIDGE ANTICLINE.—Ferrel Ridge is an anticlinal fold bringing to the surface the Oriskany Sandstone and the underlying limestones and shales in two separate outcrops in the midst of the Marcellus and Hamilton Shales.

Erosion has removed the top of the fold so that its center is composed of the Wills Creek Limestones and Shales with the upper strata of the Silurian and Lower Devonian exposed on each side. Ferrel Ridge lies to the east of the center of the fold and is capped by the Oriskany Sandstone of the eastern limb of the fold, while the upper western slope of this ridge exposes the edges of the Helderberg and Bossardville Limestones. The western limb of the anticline forms a low ridge bordering Tilhance Run and the edges of the Oriskany, Helderberg, and Bossardville are here again exposed. The western limb of the fold dips 35 to 40 degrees west, while the eastern limb dips 20 to 30 degrees east.

The western limb shows long, narrow, unbroken outcrops of the formations southward, while the eastern limb by faulting shows a duplication of outcrops. The Oriskany, Helderberg and Bossardville are thus found in two separate belts on the eastern limb of the fold by this faulting, and a diagonal shear-zone or fault throws a belt of Bossardville Limestone diagonally across the ridge to the west of Tomahawk.

The anticline dips northward and near Soho the Lower Devonian and Silurian strata disappear below the Hamilton Shales. The fold probably continues north to the river in these shales for it is described by Stose in Maryland as the extension of the Foltz Anticline traced by him in a minor fold to the river. East of Ferrel Ridge is a synclinal belt of Marcellus and Hamilton Shales, extending across Back Creek, with dips of 15 to 25 degrees, until it bends sharply up against North Mountain. West of Hedgesville, there is included a narrow outcrop of the Portage Shales which extend north toward the river.

NORTH MOUNTAIN FAULTED ANTICLINE.—The structure in North Mountain is much more complicated than in the folds so far described. It appears to be an anticline whose structure has been broken by a number of large thrust-faults so that the anticlinal structure is mainly lost.

The mountain is capped by the hard Medina White Sandstone, almost a quartzite, which is overthrust with an apparent eastern dip of 30 to 35 degrees. On the lower eastern slope, nearly at the base of the mountain, the Waynesboro Limestone of the Cambrian is faulted against the Beekmantown, and the latter is faulted against the Martinsburg Shales. Then, following up the mountain slope to its crest are outcrops of Red Medina Sandstone, White Medina, and Clinton Shales, faulted against the Oriskany Sandstone on the upper western slope of the mountain. The outcrops are greatly compressed and occur in very narrow bands.

The Helderberg Limestone and lower formations are faulted out on the western side of the mountain, while the rock outcrops on the eastern side dip strongly eastward as overturned folds. The Oriskany is in a narrow outcrop on the western slope and with the overlying Devonian Shales dips west to Back Creek.

Northward the crest of the mountain decreases in elevation from 1200 feet, southeast of Tomahawk, to 600 feet, at the Hedgesville Gap, then rises to 800 feet in a series of elongated narrow hill ridges to the river. It is cut through at the Hedgesville Gap, at a point where the Baltimore and Ohio Main Line crosses the ridge, and again on the county road west from Little Georgetown. The mountain fold seems to die out just north of the Potomac River, and extends south to the Virginia State Line. The mountain is a very narrow crested ridge with steep eastern slope, and it marks the western boundary of the Great Valley.

As the structure is followed north to near the Hedgesville Gap, the White Medina and Clinton disappear and the Red Medina is faulted against the narrow belt of Oriskany, but north of the Gap the White Medina and Clinton again appear and the former caps the ridge to the Potomac. At the gap where the railroad crosses the ridge, the Martinsburg Shale is faulted against a small remnant of Helderberg Limestone and in a short distance this limestone is faulted out and the Martinsburg Shale lies against the Hamilton Shales. Still further north the Martinsburg Shale is faulted out, and at the base of the ridge the Beekmantown Limestone has also dis-

PLATE IX.—Purslane Sandstone Cliffs Exposed on the Devils Nose up Meadow Branch Run. (Photo from Pawpaw-Hancock Folio of the U. S. Geological Survey).

appeared, so that at the Potomac, the Conococheague Limestone is faulted against the Elbrook. There is thus a northward increase in the amount of the overthrust.

VALLEY STRUCTURE.—The limestones of the Great Valley east of North Mountain and west of the Blue Ridge are thrown into a series of compressed folds—anticlines and synclines—with numerous faults, and the strata are often overthrust. Nearer the mountains the folds are more open, due possibly to relief in pressure there by faulting, according to Keith.

This folding results in duplication of outcrops, as illustrated in the belts of Stones River pure Limestone in the Martinsburg District. These folds are described in Chapter XV. The Martinsburg Shales are found in well-defined synclines which troughs extend north across Maryland into Pennsylvania, and south into Virginia in the Massanutten Syncline. The Blue Ridge is an area of extensive overthrust faulting, with a development of minor synclines on its flanks.

PREVIOUS GEOLOGICAL WORK ON THE EASTERN PANHANDLE AREA.

A number of geological observations have been made in the area of the three counties forming the eastern Panhandle Area and recorded, and some portions of the area have been studied in considerable detail. Most of these early records are journals of travellers in which they called attention to the scenery, caves, and other natural curiosities. There are a number of such articles in the scientific and literary publications of the early days.

In July, 1812, Samuel L. Mitchel recorded some notes on the Harpers Ferry region in Bruce's Mineralogical Journal for that year (p. 211) and describes especially the Government Arsenal then in operation, and calls attention to the gorge of the Potomac which he regarded as formed by accumulated waters behind the mountain barrier in the form of a large lake and finally breaking through the barrier. He also briefly describes the rocks of the Blue Ridge.

W. B. Rogers was Director of the Geological Survey of

Virginia from 1835-1841, and in his report for the year 1835 (Reprint, p. 92) described the Valley of Virginia and the natural cement rock at Shepherdstown which he found to contain nearly one-third its weight in alumina. He called special attention to the value of the limestones and marls as found in Jefferson County for use on lands as fertilizer. He states that the marls can be burned or used directly as fertilizer and says that "under these views, I would urge upon those who are particularly interested in the success of agriculture in the Valley, the benefits to be anticipated from the diligent use of the various resources so abundant and accessible throughout this portion of the State." He also called attention to the iron ores of the Valley and mentions the coal on Sleepy Creek which contains 4.94 per cent. of ash.

In his annual report for 1836, he gave an analysis of the cement rock at Shepherdstown, with 32.17 per cent. lime carbonate, 18.36 per cent. magnesium carbonate, 38.93 per cent. silica, and 4.17 per cent. alumina and iron. In his report for 1837, he gives analyses of limestones near Harpers Ferry and Charlestown and correlates the Valley Limestone with his No. II Formation and the slates and slaty sandstones as No. III.

In his report for 1838, he describes the Valley Limestone as extending southward from the Potomac in two belts separated by an intervening tract of variable width of shales which is found in a synclinal basin. He distinguished two important limestones, the dark-blue of fine grain and smooth fracture, and the dun-colored limestone of very close grain and semiconchoidal fracture and purer than the first type, and also a third type of magnesian cement limestone. In this report he mentions a deposit of hydraulic limestone on Conoloway (Tonoloway) Hill on the Potomac, used for cement on the C. & O. Canal. He also discusses the origin of the limestone iron ores, the coal of Sleepy Creek Mountain and briefly the geology of Little North Mountain. In the reports for the next three years, there is practically nothing on this area.

1876.—In 1876, M. F. Maury and Wm. M. Fontaine published for the State Board of Centennial Managers "Resources of West Virginia", in which the coal of Meadow Branch is described, the topographical features of this area, and agricultural statistics. The geological formations of the State are discussed briefly and reference made to the lower fossil strata of the eastern Panhandle Area. The mineral resources are also mentioned as, iron ores, pottery, glass sands, limestones, and mineral springs.

1877.—Persifor Frazer, in the Proceedings of the Academy of Natural Sciences (Vol. XXIX, p. 16), gave a brief description of the Meadow Branch Coal Field and stated the coal resembled some of the Schuylkill anthracite and gave an analysis of it showing 86.78 per cent. free carbon, 7.66 per cent. volatile matter, and 5.35 per cent. ash.

1880.—Hotchkiss in 1880 in "The Virginias" described the resources along the line of the Shenandoah Valley Railroad, now the Norfolk and Western.

1890.—Dr. I. C. White in Macfarlane's American Geological Railroad Guide (p. 340) briefly describes the formations from Harpers Ferry through these three counties using the New York nomenclature.

1891.—H. R. Geiger and Arthur Keith published a paper in the Bulletin of the Geological Society of America (Vol. II pp. 155-164) on The Structure of the Blue Ridge near Harpers Ferry, in which they reached the conclusion that the sandstones near Harpers Ferry are Upper Silurian and lie in synclinal troughs above the Shenandoah Limestone and that they consist of two members.

1892.—N. H. Darton in the American Geologist (Vol. X, p. 13) proposed the names Martinsburg Shales and Shenandoah Limestone for these formations as found in the Valley of Virginia and describes the rock and fossil characters of the two groups.

1894.—In this year Arthur Keith published an article—"Geology of the Catoctin Belt"—in the 14th Annual Report of the U. S. Geological Survey (pp. 285-395) which treated of the general geology of the Harpers Ferry Quadrangle. He described the various rock formations with a discussion of their lithology and age and the mountain structures. He describes the folds of the Shenandoah Valley as very uniform, being closely appressed with probably few faults. Cleavage was rare in the limestones but developed in the slaty limestones and shales. He described the base-levels of erosion and the evidences of depression and uplift with geological dates of these movements.

In this same year, he published the geological Folio of the Harpers Ferry Quadrangle, which gives in more detail the discussions included in the above paper, with maps showing the areal, economic, and structural geology (Folio No. 10).

1900.—In this year Charles H. Prosser in the Journal of Geology (Vol. 8, pp. 655-663) published an article on The Shenandoah Limestone and the Martinsburg Shale, in which he described some sections east of Martinsburg made in the upper portion of the limestone and lower part of the shales.

From his study of these sections he concluded, "There seems to be no question but that the upper part of the Shenandoah Limestone is correctly correlated with the Trenton Limestone, and the lower part contains Cambrian fossils, but the line of division is not yet determined." He also regarded the bluish to black calcareous shales just above the limestones as representing the Utica Shale of New York, while the sandy part of these shales he would correlate with the Hudson Shales as exposed in the lower Mohawk Valley and in the Helderberg region.

1903.—In this year, Wm. Griffith, Mining Engineer, published in Mines and Minerals (Feb. 1903, pp. 293-294) an account of the Meadow Branch Coal Field of Morgan and Berkeley Counties. He described the topography, geology, and structure of the field, and the character of the coal and outcrops, and reached the conclusion that the coal of this field was pockety, uncertain in continuity and thickness, with a low economic value. This paper is reproduced in full in the reports on Coal of the West Virginia Geological Survey.

In this same year appeared the Coal Report of the West Virginia Geological Survey, Volume II, by Dr. I. C. White, in which he quotes Mr. Griffith's paper and agrees with his conclusions. Dr. White suggests that in the remote future when the Pennsylvania anthracite is largely exhausted, it may be possible to mine these crushed and irregular beds of anthracite, but that time is probably many years in the future.

In this year, 1903, M. R. Campbell published an account of the Meadow Branch Coal Field in the U. S. Geological Survey, Bulletin 225 (pp. 33 and 344). He gives sections of the coal in the shafts, analyses, and a discussion of the geology and structure of the field. He advised that any commercial development of the field should be as near the center of the basin as it is possible to locate, as the crushing would be less there than on the eastern limb of the syncline. The fossils collected by him showed the formation to be typical Pocono and he regards the coal as a semi-anthracite rather than a true anthracite.

1904.—In this year a report was published by the State to advertise the resources of the State at the Louisiana Purchase Exposition at St. Louis and entitled "Handbook of West Virginia". In this book are given details on education, forestry, climate, agriculture, manufacturing, transportation, and mining. The report is mainly a compilation from various sources, and it includes many items of interest in this area. Not much is said of the mineral resources except the limestone and a brief mention of the coal on Meadow Branch.

1905.—In this year was issued Volume III of the West Virginia Geological Survey by the writer on Clays, Limestones, and Cement. In this Report, the limestones, clays, and iron ores of the eastern Panhandle Area are described with analyses and a discussion of the development of the industries. The opportunities for further development were pointed out and attention was especially called to the natural advantages in this area for Portland cement manufacture.

In this year, George W. Stose of the U. S. Geological Survey published an article on the Glass Sand Industry in Eastern West Virginia, in Bulletin 265 of the U. S. Geological Survey (pp. 473-479). In this paper he described the geology of the Berkeley Springs glass sand deposits, the character of the rock, and a description of the plants, their equipment, and quarries.

1906.—In this year, T. Nelson Dale published Bulletin 275 of the U. S. Geological Survey on Slate Deposits and the Slate Industry of the United States in which a short account of the so-called roofing slate near Martinsburg is discussed (pp. 119-

122). This article is reprinted in Volume IV of the West Virginia Geological Survey (pp. 392-396). He gave the length of the slate belt as 14 miles with width of two to three miles, and described the slates and prospect openings. He found them to be clay slates hardly fissile, strong, or elastic enough to compete with mica slates for roofing, but possibly adapted to interior use. He includes a discussion of their microscopic structure and chemical composition.

1908.—In this year was published Volume II(A), the Supplementary Report on Coal by the West Virginia Geological Survey, written by Dr. I. C. White, in which he again quotes Mr. Griffith's article on the Meadow Branch Coal Field, and finds no additional data in favor of any present economic value of this field.

In this year, George W. Stose of the U. S. Geological Survey published a paper in the Journal of Geology (Vol. 16, pp. 698-714) on the Cambro-Ordovician Limestones of the Appalachian Valley in Southern Pennsylvania. This paper treats especially of the rocks as exposed in the Mercersburg and Chambersburg Quadrangles of Pennsylvania, but his general descriptions of the limestones of that area find close application to the eastern Panhandle belt. He also gives a list of fossils from the Stones River Limestone collected near Martinsburg.

1909.—In this year, Stose published the Mercersburg-Chambersburg, Pennsylvania, Folio of the U. S. Geological Survey, in which the discussion of the preceding article is given in more detail with various references to the limestones of this area.

In this year the writer published Volume IV of the West Virginia Geological Survey on Iron Ores, Salt, and Sandstones. In this volume, the iron ores of Berkeley, Morgan, and Jefferson Counties are described, with analyses, and Mr. Dale's slate article referring to the Martinsburg area is reprinted by courtesy of the U. S. Geological Survey.

In this year the Virginia Geological Survey published a bulletin (Bulletin II-A) on the Cement Resources of Virginia, written by R. S. Bassler, in which a number of references to the West Virginia formations are made.

1912.—In this year George W. Stose and C. K. Swartz published the Pawpaw-Hancock Folio of the U. S. Geological Survey (No. 179) which includes the northern portions of Morgan and Berkeley Counties. This report gives a general description of the stratigraphy, topography, structure, and economic resources of the area, and is accompanied by maps showing these features. It is the most detailed and valuable discussion of the geology of the area so far available.

1913.—In this year the Maryland Geological Survey published its monograph in three volumes on the Devonian. While this report refers especially to Maryland, it applies almost equally well to this area and many sections and collections of fossils were made on the West Virginia side. For the stratigraphy and paleontology, this report makes a valuable contribution to the knowledge of the eastern Panhandle Area.

CHAPTER V.

THE POCONO GROUP OF THE LOWER CARBONIFEROUS.

The Carboniferous division of geological time is divided into three groups as previously given. The Permian and Pennsylvanian, which latter includes the bituminous coal fields of the western portion of the State and other States, are not represented in the eastern Panhandle Area.

The Lower Carboniferous, being below the regular Coal Measures, was also named the Sub-Carboniferous, and from its great development in the Mississippi Valley is now generally known as the Mississippian Formation. The basal formation of the coal measure group is usually a heavy conglomerate, and the lower measures were called in some of the early reports the Sub-Conglomerate Measures. The Mississippian group is separated into three well-marked and distinct divisions:

Mauch Chunk Shales.
Greenbrier Limestone.
Pocono Sandstones.

The first two divisions are important rocks in the Carboniferous geology of West Virginia and neighboring States, but they are not found in the eastern Panhandle Area, while the Pocono occurs there in two mountain areas.

The name Pocono was given to this group by J. P. Lesley, the great Pennsylvania geologist, on account of the good exposures in the Pocono Mountains of that State. It was also known and designated by the geologists of the Pennsylvania Survey as Formation No. X, and it was also described by Rogers under the poetic name of Vespertine. It was studied in detail by the various geologists of the Pennsylvania Survey, some of whose sections will be quoted in a later portion of this Chapter. While the formation lies well below the so-called Coal Measures, yet it in places contains coal seams valuable in certain fields at the north, and so holds the oldest coals known. Most of the seams are small and very slaty, but the black blossom outcrop mingled often with quite a good thickness of very black shales in localities more or less remote from coal supply has tempted capital and exploitation which have nearly always resulted in loss and failure often repeated in a series of investment cycles. This series of bad investments in coal is illustrated in the present area and further south in Virginia, dating back to the early "forties" and dating forward to the present.

The Pocono outcrops along the mountains of the eastern portion of West Virginia here and there from the Maryland Line at the Potomac to the southern part of the State, and it is found beneath the surface over the central and western portions of the State in the well borings and it is there the greatest single source of oil and gas stored in its several sandstones. Lesley describes it as the great source of salt brines, but was in error in placing the Ohio Valley brines in this formation as they come in the Pottsville above.

The Pocono is found in the eastern Panhandle area in the Purslane-Sideling Hill area in Morgan County, and in the Sleepy Creek-Third Hill Mountain area of Berkeley County. The latter area is usually described from its included valley as the Meadow Branch outcrop.

The formation in this eastern section consists of a lower group of shales and soft buff sandstone strata which grade below into the underlying Catskill, and above into a hard white sandstone and conglomerate which forms the top of the mountain in the Purslane and Sideling Hill area. In the Meadow Branch synclinal valley, the hard white sandstone is overlain by a belt of buff to gray shales with black coaly shales or slates containing anthracite coal seams of variable thickness. Over the coal shales is a heavy deposit of red shales and red sandstones which follow the rising side of the syncline to the top of the mountain eastward, and it is capped by a hard white sandstone and well-developed conglomerate which forms a portion of the crest of Third Hill Mountain. The bright red shales of this section suggest the Mauch Chunk, but fossil plants found in the upper sandstone formation were determined to be Pocono in age. The fossil plants and the lithological characters correlate the whole formation with the Pocono. It is interesting to note that Professor Rogers in those early days of state geological work in 1838 in a rapid reconnaissance survey through a practical wilderness correctly correlated the Meadow Branch strata with his Vespertine or, as it was later called, Pocono. He states in that early report for the year 1838 (Geology of the Virginias, p. 225):

"It has now been ascertained beyond a doubt that the coal in question does not appertain to that part of our series of formations in which are contained the anthracite of Pennsylvania and the bituminous coal of western Virginia and Pennsylvania, and of the great western coal field in general, but that they are of much anterior production, being included in the tenth of our series of formations, whereas the others are contained in the thirteenth. A great thickness of slates, sandstones, and sometimes limestones corresponding to formations XI and XII, intervenes between the two series of coal deposits, the lowest of which, that appertaining to X, having been, as it were, but a first effort, soon arrested, and productive only of one or two thin seams."

Rogers also determined at this early date the synclinal and overturned structure of the region and expressed the opinion that the coals on account of their fragmentary condition and slate admixture "could scarcely prove of much value in the market, being unfit for the grate and most other purposes to which this class of coals is commonly applied."

This area has attracted more or less attention from the days of Professor Rogers to the present as a possible economic source of anthracite coal many miles southward from the great Pennsylvania fields. Large sums of money have been expended in exploration work and at various times hopes have run high on the possible profits of this field. A railroad was surveyed up the Meadow Branch and the title of all the valley and mountain lands to-day is held by a coal corporation. Shafts and pits have been sunk in numerous places and coal was mined and hoisted by power from shafts, but unfortunately so far, the operations have been a total loss. It is also unfortunate for the geologist that these openings have caved in and that the shafts are full of water.

The geological sections of the regions as indicated above show a five-fold division. At the base is the sandstone and shale group, then the sandstone, then the coal shale group, the red shale and red sandstone group, and at the top the white sandstone and conglomerate. The Pocono subdivisions in northern Pennsylvania were named and the groups traced under these names over a wide area, but even there they were not followed eastward and southward. The West Virginia section is isolated from all the northern sections so that it is impossible to correlate with them and a new set of descriptive terms is required. Stose in his work for the U. S. Geological Survey on the Pawpaw-Hancock Quadrangles, which includes the northern portion of this area and the adjoining area in Maryland, gave names to these subdivisions from localities where especially good exposures were found, and these names are adopted for the local description of these formations in this Chapter. Mr. Stose has given an admirable and complete description of the Pocono in this area in his report and it is impossible to avoid more or less restatement of his work in the following descriptions and he should be given due credit for the careful separation of the formations. His subdivisions from bottom upward are:

Rockwell Formation.
Purslane Sandstone.
Hedges Shale.
Myers Shale. (Pulaski of M. R. Campbell?)
Pinkerton Sandstone.

The description of these formations in this area will now be given, followed by notes on comparison and possible correlation with sections in other areas.

ROCKWELL FORMATION.

The basal buff shales and soft buff sandstones are grouped under the name Rockwell from the exposures on Rockwell Run, whose valley separates Purslane Mountain from Sideling Hill, and in its transverse lower portion cuts across the strata at the north end of Purslane Mountain, exposing a good section of the formation southeast of Orleans Crossroads. The formation there consists of buff shales, coal seams, buff coarse-grained soft sandstone ledges with a heavy sandstone cliff at the base somewhat conglomeratic. Its upper limit is placed at the hard white sandstone. The lower limit is somewhat hard to define but it is here placed at the base of the sandstone which shows some conglomerate and is just above the typical red shales of the Catskill.

This section is somewhat obscured by the blocky sandstone debris from the upper slopes of the mountain, and it can not be given in the detail desired:

Section at Rockwell Run, Morgan County.

	Feet.	
Buff and red shales	35	
Buff shales	70	
Buff sandstone, somewhat shaly	70	
Buff shales	140	
Buff shales, sandy	105	
Blocky buff sandstone	50	
Buff shales and sandstone ledges	175	
Black slate and coal seam		
Buff granular sandstone cliff, some conglomerate	70	715
Red shales, etc., Catskill		

The ledges of sandstone show a tendency to weather into shaly layers, so that alternation of shales and sandstones depends on the locality and amount of weathering. Here and there through the section occur patches of red shales like the lower formation, but they are of small extent. The shales are quite sandy and tend to break in platy blocks of small size. This section was measured over a length of slope of a mile and by barometer readings carefully checked and may be taken as showing an approximate order of the strata.

The coal in this section was opened in a tunnel running from the run back into the mountain a little east of north for a distance of 50 feet or more, but this has long since caved and can not be examined with any results, though it was claimed the coal had a thickness of three feet. The dump is composed of slabs of micaceous sandstone, hard compact gray blocks of shale and some softer platy black slates with plant remains in them, but no good coal was found on or near the dump, nor near the old tunnel. Some slickensided coaly black pieces of slate were seen, yet it is claimed in this neighborhood that the coal was mined and burned in stoves giving good heat. Recently a square shaft has been sunk vertically twenty feet to intersect the coal in the old tunnel. This shaft is located on the point of a spur of the hill near a deep ravine, and while it is probably down to the tunnel level, no coal or even slate is found but only loose sandstone and clay debris, as though located on a slip of the mountain slope. Stose found this coal exposed north in Maryland where it has a thickness of one and a half feet of coal and black shale. He states the bed was composed of thin sheets of slickensided coal and black carbonaceous shale. The coals of the Rockwell Formation are in all probability merely streaks of thin coal and black shales and of no economic importance.

In the carbonaceous black shales in Rockwell Run, Stose found the following fossil plants as identified by David White, who referred them to the Pocono Formation:

Eskdalia.
Lepidodendron n. sp.
Megaspores.

The following plants were collected here by the writer and identified by David White:

Lepidodendron sp. ?
Eskdalia.
Sphenopteris vespertina.

Several sections of the Rockwell Formation were measured, but in all of them the strata are much obscured by the debris of the overlying heavy sandstone and while they represent the thickness of the rocks in different portions of the area, they are not at all successful in tracing the different parts of the section from place to place. All the sections given in this Chapter were measured with the slope and the thickness cal-

Section of Rockwell Formation on West Slope of Sleepy Creek Mountain.

	Feet.	
White granular sandstone, some conglomerate, Purslane		
Shaly, buff sandstone, with holes from which concretions have weathered out, shales	170	
Shales, reddish, near old spring	30	
Buff shales, sandstone ledges, soft, coarse-grained, some cross-bedded	200	
Buff flaggy sandstone with scattered conglomerate blocks	40	440
Red shales of Catskill		

It was here impossible to work out the details of the shales and sandstone but the conglomerate blocks appear to determine the lower limit of the formation, though their development was small. The sandstone at the base still is found and nearly the same thickness as at Sideling Hill, but the total thickness of the group is much less. No indication of the coal was seen anywhere in this area, though it may be covered by weathered products and the sandstone debris.

Stose measured a section four miles further north of the Whites Gap road where he found a thickness of 500 feet:

Section of Rockwell Formation, West Slope of Sleepy Creek Mountain (Stose).

	Feet.	
Massive, soft, arkosic sandstone at crest of ridge	100±	
Poorly exposed, buff, sandy shale and sandstone, with some red shale and sandstone near the top	370±	
Conglomerate containing quartz and a few jasper pebbles, and gray arkose	30	500±

OUTCROPS.—The Rockwell Formation outcrops in long narrow belts on each upper slope of Purslane-Sideling Hill Mountain, with a width of 500 to 2,000 feet, and forms the end of the mountain at the north where the Potomac has cut through. A small outcrop is found southeast of Pawpaw on Spring Gap Mountain.

The Rockwell Formation outcrops on the upper western slope of Sleepy Creek Mountain and on the upper eastern slope

PLATE X.—Deep Cut near Pawpaw on Magnolia-Pawpaw Low Grade Line of Baltimore and Ohio Railroad, showing Catskill Shales and Sandstones with Overlying 25 Feet of Alluvium.

of Third Hill Mountain in long narrow belts similar to those at the west. It bends around the north ends of these two mountains up into the Meadow Branch Valley as far as the Devils Nose. The thickness varies in the whole area from 440 to 715 feet, with an average thickness of about 600 feet.

The upper limit of the formation is placed at the base of the white sandstone and conglomerate ledges of the overlying Purslane, but the lower limit is often difficult to locate. In the Sideling Hill area, there is in many places a conglomerate buff sandstone near the base which is taken for the basal member, but in the Meadow Branch area this conglomerate is but rarely seen and the formation grades into the underlying Catskill. The base is then assumed to be at the lower limit of the buff coarse-grained sandstone ledges and above the distinctly red Catskill Shales and Sandstones. On account of the sandstone debris over the steep mountain slopes, this line is often obscured and then it is impossible to accurately define the division plane between the two formations. This fact may account for the range of thickness in some of the sections as a portion of the Catskill may be included. The shales seem to be non-fossiliferous, except in the coal shales which are rarely uncovered. Sandstone debris appears to have completely hidden this coal outcrop in the Meadow Branch region. The sections show an alternation of buff shales and buff soft sandstones. The shales are sandy and break in plates and in many cases represent the weathered sandstone ledges. The sandstone is a coarse sand, with a few scattered small flakes of mica, containing some white spots like kaolin, and they are quite soft. Reddish shales occur here and there even to the top of the formation and show a similarity to the underlying Catskill. Some of the sandstone ledges contain clay concretions which have weathered out, leaving holes in the sandstone. Conglomerate ledges occur but the pebbles are usually few in number and scattered through the rock. The sandstones are too soft for road material or building stone and the entire formation has no economic importance.

PURSLANE SANDSTONE.

Above the softer beds of the Rockwell Formation is a group of hard white sandstones and conglomerates, some of the beds being almost quartzites, and they cap the mountains and form their crests over much of their length. Stose named this group the Purslane Sandstone from the exposures on that mountain. The sandstone is often snow-white in color and in other ledges carries a reddish stain. It is usually fine in grain and exceptionally hard, often giving a distinct sulphur odor when struck with the hammer. It forms massive cliffs which on account of its resistance to erosion form pinnacles, castles, and high walls. The conglomerates are composed of white and rounded pebbles of opaque milky quartz, in size from one-fourth to one-half inch across. The conglomerate may be in a distinct ledge or again forms a vein or band along joint faces. The pebbles are firmly cemented and the rock is usually hard and durable under weathering. In places the sandstone becomes flaggy and softer, and shales of sandy character occur. In the typical sections, there appear to be three massive sandstones, one at the bottom, one at or near the top, and one about the center of the section.

Near the top of the Purslane on Sideling Hill occur some black shale and coal-like fragments which have there been prospected, but no good coal was found. On Third Hill Mountain, a number of prospect holes for this coal were made in the softer portion of the formation. These have exposed some buff sandy shales and flaggy sandstones, but not even the black slate was discolored here. One of these prospect tunnels was driven some distance into the mountain on the east slope of Third Hill Mountain near the old road one and a half miles south of Pinkerton Knob. The dump shows a mass of slabby sandstone and coarse buff sandy shales, but no black shale or trace of coal.

OUTCROPS.—This formation covers the entire top of Purslane Mountain and the greater portion of the top of Sideling Hill. The valley of Rockwell Run, which separates these two mountains, is cut into but not through it. In the transverse portion of the valley of this run, the sandstone is cut through and shows high steep cliffs of solid sandstone. It extends north to the gap of the mountain at the Potomac where it forms the crest of the gap while the lower portion near the river is cut through the underlying Rockwell. The level-top ridge of the mountain, with its Purslane cover, is narrow at the northern and southern portions of the mountain and it disappears near the southern line east of Pawpaw. A number of outliers of the sandstone occur through Purslane Mountain, usually on higher knobs and to the south on Sideling Hill. A small outcrop of the sandstone is found on the crest of Spring Gap Mountain. The debris of this sandstone covers the slopes of the mountains down into the valleys.

The Purslane Sandstone forms the crest and inner eastern slope of Sleepy Creek Mountain in a broad belt. It also occurs as a narrow belt along the upper eastern slope of Third Hill Mountain and Short Mountain. It forms the crest to south of Pinkerton Knob. The sandstone curves around the north ends of these mountains and up the Meadow Branch Valley, the two belts from the east and from the west uniting near the Devils Nose in vertical rugged cliffs forming wildly picturesque scenery. Its thickness varies from 150 to 245 feet in the sections measured, though a greater thickness may occur on the eastern slope of Sleepy Creek Mountain, but the great mass of debris there makes it very difficult to secure any accurate measurements. Stose measured 310 feet near the Devils Nose.

Fossils are almost absent in this sandstone though casts of Lepidodendron were found in the lower part of the section in Meadow Branch below the Devils Nose. The plant remains in the underlying Rockwell are of Pocono age and plant remains in the beds above are of the same age, so that this sandstone is Pocono.

The following sections show a greater thickness in the Meadow Branch area than on Sideling Hill, an opposite condition to that of the Rockwell. The sections agree in having a solid ledge of hard sandstone at the top and bottom, with shaly and flaggy ledges between:

Section of Purslane, East Side of Sideling Hill, East of Lineburg.

	Feet.	
White sandstone ledges in four- to six-inch courses..	20	
Sandstone, flaggy, breaks down into platy shales.....	50	
Sandstone, white, compact, and hard................	70	
Sandstone, flaggy, hard............................	15	
Sandstone, coarse-grained, and hard................	25	180

Section of Purslane, East of Orleans Roads.

	Feet.	
Red shales..	70	
Black slate, coal prospect..........................		
Flag sandstone in two-inch courses..................	10	
Concealed, but scattered blocks of sandstone........	70	
Flaggy sandstone, stained reddish...................	15	
White sandstone wit conglomerate....................	30	195

These two sections about four miles apart on Sideling Hill show a close agreement in thickness but a very different order of strata near the top. The coal prospect shows black shale or slate, but no coal could be found on the old dump. Above the coal and for a few feet below it comes a belt of red flaky shales, in appearance very similar to those of the Meadow Branch Valley. Its thinness and lack of the strata between the red shale and Purslane in Meadow Branch would suggest that this is only a local phase in the sedimentation. At no other place was this red shale found at this horizon, and it seems to disappear to the north and south of this particular section.

Stose gives two partial sections of the Purslane further north on Sideling Hill in Maryland (loc. cit. p. 103):

Partial Section of Purslane Sandstone on Sideling Hill, above C. & O. Canal (Stose).

	Feet.	
Black shale and thin coal, with tough sandy underclay containing Stigmariae at base...........	4+	
Thin-bedded, cross-bedded sandstone, weathering with reddish stain...........................	40	
Massive coarse white sandstone with quartz pebbles	30	
Covered	50	
White cross-bedded sandstone, tarnished red on weathered surfaces..........................	20	144+

Partial Section of Purslane Sandstone on National Pike over Sideling Hill (Stose).

	Feet.	
Thick-bedded white sandstone	20±	
Thin-bedded hard sandstone	10	
Covered	8	
Black carbonaceous shale containing plant remains	2	
Gray shale containing plant remains	4	
Thin sandstone containing carbonaceous matter	4	
Massive hard sandstone with quartz pebbles	20	
Gray shaly sandstone, weathering rusty, and rusty shale with calcareous concretions and quartz pebbles	40±	
Hard gray sandstone with quartz pebbles	20	132±

These two sections, four miles apart, show the coal shales with plant remains, but quite thin and underlain by clays or shales with plants. The basal sandstones are, in part, conglomerates. The thickness is less than to the south of the Potomac, but Stose states that they are partial sections. There is no trace of the red shales as found on the Orleans road.

The following section was measured up the steep hill at Devils Nose at the north end of Sleepy Creek Mountain. It was measured with hand level and calculations made for slope and dip. The section is 66 feet less than the one measured near this place by Mr. Stose, possibly due to difference of location of the section at this place. The base of the section is taken at the top of the cross-bedded, flaggy sandstone regarded as Rockwell in the run. This place is near the bottom of the synclinal trough and the strata dip at a low angle, about 12 degrees at the bottom and top. The white sandstone near the top projects in overhanging cliffs, forming in one place the so-called "Nose", and large shelf blocks have fallen to a terrace below.

Section of Purslane at the Devils Nose, Meadow Branch.

	Ft.	In.
White sandstone, coarse in texture, solid ledge	26	0
White sandstone, mottled with shale pebbles	10	0
White sandstone, quite hard	10	0
White sandstone, small pebble conglomerate	8	0
Coarse-grained, white sandstone, small pebbles (The Nose)	5	2

	Ft.	In.
White vitreous sandstone, almost a quartzite, gives sulphur odor when struck, weathers buff........	41	6
Granular buff sandstone much jointed, ledges 2 to 10 inches	10	4
White almost quartzose sandstone, somewhat reddish tinged, and few mica flakes....................	10	4
Light gray micaceous sandstone, solid ledges........	20	8
Yellowish gray granular sandstone, stained reddish in some ledges....................................	10	4
Greenish gray sandstone...........................	10	3
Reddish brown sandstone..........................	15	6
Shaly sandstone, purplish brown, micaceous, flaggy..	15	6
Greenish gray granular micaceous sandstone........	20	8
Coarse gray sandstone stained reddish on outside...	15	6
Reddish granular sandstone, micaceous..............	14	6
	244	3
Cross-bedded buff to grayish-brown sandstone regarded as Rockwell in run......................		

Some of the lower ledges of sandstone in this section are cross-bedded, but this structure is characteristic of the upper ledges at the Nose itself. Above this point the sandstones form massive cliffs. The upper ledges show a fine conglomerate feature, the pebbles being white and not over a half inch across, many very small, and they are scattered through the rock. These upper sandstones are very white on fresh fracture, but weather to a buff and often reddish stained. I could find at this place no trace of the conglomerate near base of section. The middle ledges of the section are more or less micaceous and tend to break in flaggy courses, especially when weathered. The ledge near the top is peculiar in being mottled by flat dark shaly pebbles. Some of these upper ledges are almost quartzites and exceptionally hard, giving a strong sulphur odor when struck with the hammer, a character quite in accord with the name of this locality. A short distance south of this place, the walls of the Purslane Sandstone close in forming a steep-walled canyon through which the creek flows. The bed of the run is filled with large boulders of Purslane, some of which are almost eight-foot cubes, and the water tumbles over solid ledges in waterfalls and rapids. Some distance to the north of this place, a coarse white pebble conglomerate is found near the base of the Purslane, but it seems to disappear as followed south.

By condensing the above section, there is shown an upper sandstone stratum quite solid and white, then a more or less foliated stratum separating the upper sandstone from a middle sandstone stratum. Below is a series of micaceous, foliated sandstones, coarser in grain, and at the bottom of this section a massive but somewhat foliated sandstone, while in other possibly more typical sections this horizon is marked by a solid sandstone stratum often a conglomerate.

Devils Nose (Purslane) Section, Condensed.

	Ft.	In.
White, solid, hard sandstone, some conglomerate....	100	8
Buff sandstone, much jointed, foliated...............	10	4
White quartzose sandstone.........................	10	4
Greenish-gray sandstone, often stained reddish, micaceous, more or less foliated....................	92	11
Coarse gray sandstone, micaceous, stained reddish...	30	0
	244	3

HEDGES SHALE.

In the Purslane-Sideling Hill area, the two preceding formations complete the Lower Carboniferous or Mississippian, but in the Meadow Branch area there is a series of shales and sandstones above the Purslane several hundred feet in thickness.

Directly above the Purslane in Meadow Branch Valley and on the slopes of Third Hill Mountain is a group of buff sandy shales and thin foliated sandstone ledges, with black shales and semi-anthracite coal. This formation was named by Stose the Hedges Shale from Hedges Mountain, a spur on Third Hill near which are located coal prospects. Its limits are easier to describe than to locate in the field. The lower limit is marked by the hard Purslane Sandstone, and its upper limit is the **red shale** of the next formation, the base of which is often a solid red sandstone. Its outcrop of soft rocks readily disintegrates by weathering, and it is always more or less covered by the Purslane Sandstone debris, and to some extent in the run valley by alluvium. It is thus very difficult in the field to accurately define the limits, more especially the lower one. The numerous coal openings over the area are very useful in locating the belt of shales of this formation, but they are mostly caved in at the present time and they do not afford much data on the group except from a study of the dumps. The outcrop boundaries on the map represent the approximate limits.

This group contains at least three coals which are repeated by folding and overthrust so that the prospects are located in the bed of the run, near the top of the mountain and in between. The larger shafts in the coal are close to the run opposite Whites Gap through Sleepy Creek Mountain, and near the top of Short Mountain, but the prospect holes may be found almost everywhere in this area. These prospects and the coals, their composition and characters, will be described in the Chapter on Mineral Resources in a later portion of the present volume. The coals are semi-anthracite in slickensided blocks mingled with slate also polished and often looking like the coal. This slate is so thoroughly intermixed with the coal and all crushed together that it is a matter of great difficulty to separate them in quantity. When separated from the slate, the coal is of high quality. One coal horizon is near the base of the shales, one near the top, and one about the middle of the section. The coal vein varies from two feet to over nine, and this variation often takes place in a few feet. Not enough exploration has been done to estimate average thickness on account of the amount of variation.

The thickness of the Hedges Shale is about 180 feet, according to the following section, which was measured to the south of the Devils Nose, but the details of the section are very poor on account of the concealed character of the outcrops:

Section of Hedges Shale South of Devils Nose.

	Feet.	
Buff sandy shales	12	
Coal in black slate		
Buff shales	50	
Coal and black slate		
Buff sandy shales and shaly sandstone ledges	108	
Coal in black slate		
Buff sandy shales	10	180
Reddish shales of the Myers Formation		

Mr. Stose measured the following section on the mountain road to the east of the Myers Place (loc. cit. p. 106):

Partial Section, Hedges Shale on Third Hill Mountain, East of Myers (Stose).

	Feet.	
Black shale and thin coal seam	10±	
Massive granular thin-bedded white sandstone	15	
Covered	40±	
Thin-bedded hard sandstone	1	
Carbonaceous shale and thin sandstones with coal streak and plant remains	15	
Covered	10±	
Gray and black shale and thin sandstones	1	
Covered	10±	
Thin slabby sandstone	2	
Dark shale and coal streak	2	106±

OUTCROPS.—The **Hedges Shale** is found near the eastern base of Sleepy Creek Mountain through the length of Meadow Branch Valley to a point about one-half mile south of Devils Nose. The belt is about 800 to 1,100 feet wide. It is also found on the upper inner slope of Short Mountain, where it is brought up on the upper limb of the syncline. It is seen on the upper east slope of Third Hill Mountain as a narrow belt of overturned strata, 200 to 250 feet wide. South of Pinkerton Knob, the belt passes over to the west slope of the mountain and close to the top of the ridge. A small synclinal trough of the shale is found in the Purslane Sandstone on the crest of the mountain about two and a half miles south of Pinkerton Knob on the wagon road across the mountain to Myers.

The coal shales contain numerous plant remains, in fact, some of them are a mass of stems, roots, and fronds of ferns. As the mines are caved or full of water, it is impossible to make any extended collections of these plants, and those on the dumps are in badly weathered and disintegrated shales. Stose gives the following list of plants in this shale, which he collected, as identified by David White:

Sphenopteris vespertina.
Triphyllopteris lescuriana.
Triphyllopteris virginiana.
Protolepidodendron scobiniforme.
Lepidocystis siliqua.
Triletes sp.
Carpolithes sp.
Eskdalia sp.

David White in the folio report of Mr. Stose comments as follows on the fossil plants of this coal field:

"The collections in this region typically illustrate the paucity of species characteristic of the Pocono along the eastern border of the basin, though plant fragments, many in fine condition, are very abundant, as is natural, in the roof shales over the coals of that age. I have seen but a few species, which appear to have almost exclusively occupied the ground, doubtless furnishing the land-plant material for the composition of the coal throughout the coal-bearing series, extending from near Pottsville, in eastern Pennsylvania, to the vicinity of Wytheville, in southwestern Virginia."

The plant remains in these coals appear to be Pocono in age, according to the work of David White.

The following plant fossils were collected from the dumps of the mines in Meadow Branch during the present work and were identified by David White:

Lepidodendron scobiniforme, Meek.
Triphyllopteris. sp. undet.
Triphyllopteris lescuriana.
Lepidodendron eskdalia.

MYERS RED SHALE (Possibly PULASKI of M. R. Campbell).

Above the Hedges Shale in the Meadow Branch Valley is a series of red beds, shales and sandstones. The shales are deep red in color, sandy, and break in smooth plates, while the sandstones are coarse-grained, soft, with scattered mica points or minute scales. They break shaly and many of them weather to shales. They are in some cases deep red in color, and in others are a reddish-buff color. The soils of the area are red and apparently very fertile. At the base of the formation in the lower part of the valley is a heavy red sandstone stratum that forms vertical cliffs a hundred feet in height. This sandstone forms a vertical wall on the east bank of the run in the vicinity of Little Mountain and north. The sandstone dips at this place about 15 to 20 degrees southeast and is overlain by a heavy deposit of the red shales. At Little Mountain, the run cuts through this little hill in a steep-walled gorge of this sandstone. In the upper portion of the valley, this heavy sandstone ledge does not appear, but is replaced by shales and small ledges of red sandstone. The thickness of the shales runs from 800 to 935 feet, but like the preceding group of shales the soft character of the material and the sandstone debris from the mountain make it very difficult to secure any complete or detailed sections. The formation was named by Stose from the Myers place in Meadow Branch Valley, where it is typically exposed. Many years ago, this was a famous grazing ranch, but at the present time is abandoned and there is not a family living in the whole valley and few cattle are pastured there. The vineyards and fine orchards still in good bearing near the Myers place show that the valley soil in these red shales is highly productive.

OUTCROPS.—The **Myers Red Shale** is found only in the Meadow Branch Valley where it covers most of the valley floor east of the run. It follows the rising limb of the syncline up the westward slope of Third Hill Mountain to its crest, and in much of this mountain area extends over the crest to the east slope. South of Pinkerton Knob, it is confined to the west slope of the mountain. On Pinkerton Knob and in another area to the north it extends to the overlying sandstone on those two ridges. Its width over most of the mountain and valley exposures is one-half to three-fourths mile.

The following section was measured on the west slope of Third Hill Mountain east of Whites Gap through Sleepy Creek Mountain:

Section of Myers Shale on Third Hill Mountain Opposite Whites Gap.

	Feet.	
Hard white sandstone and conglomerate (Pinkerton)		
Soft red sandstone, weathering buff, slightly micaceous, red and buff shales	200	
Red shales and thin sandstone ledges	170	
Red shales, three-foot ledge red sandstone	100	
Red sandstone ledges and red shales	100	
Buff shales	50	
Red sandstone, blocky, weathers buff, shales	145	
Buff shales and sandstones, some red ledges	120	
Red platy shales	50	935

This section lacks in details due to concealed nature of outcrops. It shows mostly red shales with included ledges of red sandstone which show a marked tendency to weather into shales. The lower sandstone was not found in this section, but further north reaches a thickness of 50 to 60 feet, forming the steep east wall of the run.

Fossils are rarely found, but in the lower sandstone a short distance north of Little Mountain an impression of *Lepidodendron* was observed. These red shales over the heavy sandstone below resemble the Mauch Chunk Shales of Pennsylvania, but the calcareous beds of that shale are absent here, and there is no trace of the overlying Greenbrier Limestone which is a very persistent member of the Lower Carboniferous through West Virginia. There were found also in the overlying shales fossil plants identified as Pocono in age. These red beds are therefore Pocono in age and similar to the Pocono red beds found in some of the Pennsylvania sections and in the well records of this State.*

PINKERTON SANDSTONE.

Over the Myers Red Shale in the Third Hill Mountain area in two places is found a heavy sandstone and conglomerate formation named by Stose the Pinkerton Sandstone from its exposure on Pinkerton Knob. It is a hard white sandstone with a large amount of coarse conglomerate full of white rounded pebbles. The conglomerate is very characteristic in the more northern outcrop opposite Little Mountain. It thus resembles very much the Pottsville Conglomerate at the base

*The **Myers Red Shale** of Stose may possibly correlate with the **Pulaski Red Shale** of M. R. Campbell, described first in the Pocahontas, West Virginia, Folio of the U. S. Geological Survey, issued under date of April, 1895. No details are given by Campbell as to whether or not there is an upper member of sandstone immediately under the Greenbrier Limestone, and this is the only reason for doubt. In the oil well borings of Kanawha, Clay, Nicholas, Fayette, and other counties of the southwestern region of West Virginia, a red horizon makes its appearance at 50 to 75 feet below the top of the Big Injun Oil Sand, and has been noted in many well borings. Whether or not this is the representative of the Pulaski Red Shale of Campbell has not yet been determined, but there can be little doubt that it represents the **Myers Red Shale** of Stose. (I. C. W.)

of the Coal Measures, but above this rock at one place is an old coal prospect which apparently failed to find coal of any value, but which has disclosed light-gray shales with plant impressions which were found to be of Pocono age.

At several places over the mountain, pits have been sunk for coal, but they show only sandstone blocks and coarse shaly sandy shales or shaly sandstone. The opening which exposes the fossil plant shales is to the southeast of Hedges Mountain near the crest of the ridge and about 200 feet west of the mountain trail along the ridge. The opening is an old one and the shales are badly disintegrated. Stose collected the following fossil plants here, as identified by David White:

Lepidodedron sp.
Lepidodendron cf. *corrugatum* (=*Protolepidodendron*)
Eskdalia sp.
Megaspores.
Triletes, form with thick glossy exine.

Mr. Stose quotes David White on the age of these shales as indicated by these fossil plants, as follows:

"Notwithstanding the considerable body of red shales and sandstones between the coal-bearing division (Hedges Shale) and the conglomerates with the thin coal (Pinkerton Sandstone) in the upper portion of the syncline, I can find no evidence of post-Mississippian age. On the other hand, the very small amount of fossil material is not only characteristic, so far as known, of the older Mississippian, but it is closely related to the Pocono flora itself. A similar association of the same forms, likewise preserved in coaly shales, is observed in the Allegheny Valley just above the group of sandstones and shales there correlated with the Pocono."

OUTCROPS.—The Pinkerton Sandstone outcrops in a small area on and around Pinkerton Knob of Third Hill Mountain, and in a larger area to the north, extending from a point south of Whites Knob to west of Hedges Mountain, with a length of two miles, and a width of about 1,500 feet.

Stose secured a measurement of 125 feet for the thickness on Pinkerton Knob. The following section at about the middle of the northern outcrop, or about opposite Whites Gap through Sleepy Creek Mountain, shows a thickness of 114 feet:

Section of Pinkerton Sandstone Opposite Whites Gap.

	Feet.	
Buff shales and light-gray shale with plant remains..	10	
Reddish-brown platy sandstone, 2- to 4-inch ledges...	8	
White sandstone and pebble conglomerate..........	20	
Buff sandstone and shales..........................	40	
White sandstone, flaggy............................	8	
Hand white sandstone, reddish tinged, some conglomerate ledges..................................	20	114

A prospect hole was excavated in the reddish-buff shales near the top of the ridge and near the top of the section, but it showed no plant shales or trace of coal, but showed a number of concretionary limonite iron nodules. Other holes have been dug above the conglomerate but showed nothing of value or interest.

The reddish flag sandstone near the top of the section was observed near Pinkerton Knob, and it is found at a number of places in the larger area to the north. Opposite Hedges Mountain, the top of the ridge is marked by a massive conglomerate composed of loosely cemented white pebbles with an eastward dip of 60 degrees on the overturned fold. Some of the upper shales have a reddish tinge. The buff sandstone of the section is in other parts of the area nearly white, but weathers to a buff color.

CORRELATION OF THE POCONO FORMATION.

The isolated outcrops of Carboniferous strata in this area appear to represent southward outliers of the Pennsylvania Pocono, and the typical sections in that State show some resemblance to those of this area. The relation of the sandstones to the softer shales and the presence of red beds in some of these Pennsylvania sections are very similar to the West Virginia sections.

In Huntingdon County, Pennsylvania, which is in the direction of the trend of the Carboniferous rocks of Sideling Hill and on the continuation of this ridge into that county, C. A. Ashburner made a very detailed section of the Pocono in the railroad tunnel and cut across that ridge, which section

Lesley described as furnishing "the most interesting and instructive data we have respecting the character of the Pocono formation".

This section is here reproduced in much condensed form from Mr. Ashburner's report (F, pp. 206-216):

Sideling Hill Section of Pocono in Huntingdon County, Pa. (Ashburner).

	Feet.	
Upper Sandstone Group.		
Massive gray coarse-grained sandstone, alternating with thin-bedded and flaggy sandstone and shale of same color	580	
Alternating massive gray and greenish-gray sandstone with a foot seam of black slate showing minute plant impressions	30	
New River Coal Series (a mistake of Lesley's—I. C. W.)		
Massive gray sandstone with thin partings of coal	88	
Gray sandstones, some with pyrites nodules, and thin coal seams	77	
Shale sandstone and coal seams	96	
Soft sandstone and coal, some with false bedding	52	
Middle Conglomerate Group.		
Black carbonacecous shales, some sandstone	60	
Massive gray sandstone, some conglomerate	113	
Gray flaggy sandstone and gray shales, some black slate	207	
Lower Green Sandstone Group.		
Dark bluish-gray sandstone and gray and green shales	77	
Coarse-grained sandstone, reddish-gray and yellow	177	
Yellow, gray, and green, shaly sandstone, and yellow shales, some olive sandstone with iron concretions	136	
Partly concealed, soft, green and olive sandstones, alternating with soft yellow flaggy and hard massive gray sandstone	440	2133

Another interesting section of the Pocono was measured in this same county by Dr. I. C. White at the Riddlesburg Gap in Terrace Mountain. Lesley states that "the crests of Terrace Mountain and of Sideling Hill come together in the magnificent knob, rising majestically from the right bank of the Juniata River some miles below the city of Huntingdon, from the summit of which a superb panorama of mountain ranges and fertile valleys well repays the artist and geologist for the fatigues of the ascent". This section is condensed from Dr. White's section as given in Report T3, p. 81:

Riddlesburg Gap Section of Pocono, Huntingdon County, Pa. (I. C. White).

	Feet.	
Gray sandstone and dark shales with broken plants	104	
Gray sandstones and black coal shales	125	
Conglomerates, sandstones, some shale	197½	
Red, olive, and yellowish shales	70	
Gray sandstone and yellowish shales	112½	
Dark shale very fossiliferous	50	
Massive sandstone and sandy shales	85	
Red and yellow shales and gray sandstones	218	
Massive gray sandstone	140	
Red shales and greenish sandstones	340	1442

In the same district, Dr. I. C. White measured another section of Pocono at the Shoups Run Gap in Terrace Mountain which is given in the Report above quoted and which is here reproduced in much condensed form:

Shoups Run Gap Section in Terrace Mountain, Huntingdon County, Pa. (White).

	Feet.	
Gray sandstone, pebbly	210	
Gray sandstones and dark shales	450	
Red shales and greenish-gray sandstone	70	
Blue-black slate with a few thin flags, at the top impressions of *Lepidodendron*	100	
Gray sandstone and sandy shales	30	
Massive gray sandstone	270	
Greenish-gray sandstones and red shales	250	1380

In the State of West Virginia very few sections of the Pocono are available for study. Mr. Ray V. Hennen made a very careful section of the Pocono in Preston County which is given in the Report on that county by the State Geological Survey (p. 99), which is here given in somewhat condensed form:

PLATE XI.—View of the Baltimore and Ohio Railroad Cut shown in Plate X, in the town of Pawpaw.

Section of Pocono near Rowlesburg, Preston County (Hennen).

	Feet.	
Sandstone, massive, limy near top	213	
Sandstone, flaggy, with thin gray shale	65	
Sandstone, massive, and dark shales	95	
Sandstone, massive and flaggy, and shales	71	
Dark-gray sandstone and limy gray shales	57	
Sandstone, nodular, and gray sandy shales	11	
Sandstone, massive at top, shaly at base	15	527

The above sections with the Meadow Branch Section are further condensed into a four-fold division in the following table for purpose of comparison:

Sections of Pocono in Pennsylvania and West Virginia.

	Sideling Hill.	Riddlesburg.	Shoups Run.	Meadow Branch.	Preston County.
Gray sandstone, red and buff shales, some plants	610	609	730	925	213
Buff and black shales, coals, some gray sandstones	313	50	130	180	65
Massive gray sandstone and conglomerate, gray shales	380	85	270	244	95
Greenish sandstone, red and buff shales	830	698	250	700	154
Totals	2133	1442	1380	2049	527

While the sections show considerable variation in thickness in the different groups, there is more or less agreement in the order of the strata and an approximate correlation can be made. The lowest division shows a similarity in thickness in the Sideling Hill, Riddlesburg, and Meadow Branch Sections. The top division is thicker in the Meadow Branch Section through the great development of red shales, though the total thickness of the first two groups is similar in the Sideling Hill and Meadow Branch Sections and this is true of the total thickness of these two sections. The total thickness of the first two divisions in Meadow Branch and Shoups Run shows an agreement. The decrease in total thickness in Shoups Run is due to decrease in the lowest division. This comparative table shows the resemblance of the Pocono in the four-fold division and in the thickness of the groups, though at Riddlesburg the two middle divisions show greatly decreased thickness. The lowest division grades into the underlying Catskill and the differences in thickness in the different sections in this division may be due in part to the inclusion of some Catskill beds with the Pocono at this point.

The Preston County Section illustrates the westward thinning of the Pocono in all the four divisions, but compared with the Riddlesburg Section, the thinning is especially prominent in the top and bottom divisions.

The Pocono in northern Pennsylvania, for example in Wayne County, according to Stevenson, shows a bottom and middle conglomerate and a top sandstone, with shales and cross-bedded sandstones between the top and bottom divisions, with a total thickness of 1,140 feet. The Pocono reaches its greatest thickness in that State to the southeast, 1,800 feet at Pottsville and 2,000 feet on the Susquehanna. The conglomerate rock seems to be characteristic through all these eastern Pennsylvania sections. According to Stevenson, the most eastern outcrop is found in Fulton County with 1,100 feet thickness, and decreases westward so that in Lycoming County it is 480 to 665 feet, composed of shales and cross-bedded sandstone, but no conglomerate. In Allegany County, Maryland, the thickness is 258 feet of grayish-green flaggy sandstone with some shales and a few bands of conglomerate, according to Mr. Martin. In Westmoreland County, Pennsylvania, and near the Ohio River, the thickness is 440 feet, and in Preston County, this State, Hennen measured the Pocono as 527 feet thick.

Stevenson states that this rapid thinning westward in Pennsylvania is apparently due to the loss of the lower beds and that the formation becomes more and more shaly in that direction. He also states that the Pocono decreases in thickness from 500 feet in southern Ohio near the river to 175 feet in northern Alabama and is wholly gone before reaching the middle of that State.

Fontaine found in Augusta and Rockingham Counties, Virginia, a three-fold division of the Pocono, with a lower division of sandstone, a middle of sandstones and shales with coal streaks or coal seams, and an upper division of red shales and sandstone with a total thickness of 450 to 700 feet, which would represent a further thinning southward from the sections in West Virginia.

Fontaine found at Caldwell Station, six miles west of White Sulphur Springs, a four-fold division of the Pocono. At the top were 250 feet of red crumbling marlites under the Greenbrier Limestone; below this group, he found 290 feet of sandstones, in which were carbonaceous streaks, which represented his middle division in Augusta County, according to his correlation; then came a coarse, more or less conglomeratic sandstone, 80 feet thick; and below the bottom division, consisting of transition beds of yellow flaggy sandstone weathering brown, 500 feet thick, giving a total thickness for the Pocono of 1,160 feet. This section arranged in tabular form with the Meadow Branch Section shows a marked decrease in the two lower divisions, and a decrease of the top with the loss of the overlying conglomerate sandstone of the Meadow Branch Section:

Sections of Pocono, Northern and Southern West Virginia.

	Southern.	Northern.
Sandstones and red shales..................	250	925
Sandstone, shales, and coal streaks..........	290	180
Massive sandstone, conglomerate............	80	244
Buff sandstones and shales..................	500	700
Totals	1120	2049

The oil wells in many sections of West Virginia are drilled into and through the Pocono whose sands are the greatest source of oil and gas in the State. The different sands of the Pocono have been named by the oil well drillers as follows: **Big Injun Sand,** which comes under the Big Lime (Greenbrier) and described by Dr. I. C. White as "a hard and often fine-grained gray sandstone with usually two, and occasionally three or four open, coarse, porous, and sometimes pebbly layers, filled with oil, gas, or salt water." It varies in thickness from 140 to 300 feet.

On the western border of the State, the upper 20 to 30 feet of the Big Injun Sand is separated from the main mass by five to fifteen feet of dark slate and this upper portion is called the **Keener Sand.** Twenty to forty feet below the Big Injun is the **Squaw Sand,** 20 to 30 feet thick. At the base of the Pocono is the **Berea Grit,** 2 to 30 feet thick, a very productive oil and gas horizon in the western, central, and southwestern portions of the State.

It would be impossible to accurately correlate these oil and gas sands with the divisions of the Pocono in Morgan and Berkeley Counties, but the upper conglomerate and sandstone mass above the red beds, or the Pinkerton Sandstone is probably the Big Injun, while the Purslane Sandstone may represent the Berea Grit, as the lower measures below that sandstone seem to thin and disappear westward.

The various well records of the State show that the Pocono has thinned greatly westward from the outcrops in Pennsylvania and in the eastern Panhandle Area, and most of the wells show some thinning of the measures west of the Preston County Section. The following records are taken for the most part from the Report on Oil and Gas by Dr. I. C. White [Volume I-(A)]. In Harrison County, the thickness of the Pocono in the oil wells varies from 336 to 490 feet; in Doddridge, 355 to 458 feet; in Ritchie County, 380 to 415 feet; in Wood County, 447 to 515 feet. To the north, the thickness increases, reaching 519 feet near Wheeling and 615 feet in one well near Wellsburg.

In many of the well records red shales were recorded in the Pocono and probably more are actually present in the different wells as much of the logs are marked unrecorded. These red shales are noted in the logs of the wells in Preston, Harrison, Kanawha, Summers, Barbour, and other Counties.

The detailed well records usually show only a three-fold division of the Pocono into the upper sandstone, Big Injun; the lower sandstone, Berea; separated by shales and thin sandstones. The fourth division below the Berea as seen in the Morgan and Berkeley County Sections and in the eastern Pennsylvania Sections is not separated in the well records and is probably absent. The westward thinning of the Pocono as suggested by Stevenson may be due to the loss of lower members of the section so that the fourth or lowest division may be entirely absent which seems highly probable, though this absence may be due to the imperfections of the well records.

The following well records from the State Reports will illustrate the three-fold division of the Pocono and also the thickness of this formation in a number of counties:

Well Records of the Pocono.

	Catlettsburg.	Big Sandy	Huntington.	Wirt Co.	Wood Co.	Parkersburg.
Big Injun Sand...	150	100	177	135	190	205
Shales and sandstones	329	467	405	410	308	391
Berea Grit.........	51	60	25	15	6	13
Totals	530	627	607	560	504	609

	Ritchie	Gilmer	Harrison	Pittsburgh	Steubenville
Big Injun Sand............	75	63	174	310	215
Shales and sandstone......	245	217	380	105	362
Berea Grit................	60	40	15	50	4
Totals	380	320	569	465	581

NOMENCLATURE OF THE POCONO GROUP.

In the work of the Pennsylvania Geological Survey, names were given to the subdivisions of the Pocono especially in the northwestern portion of the State where Dr. I. C. White traced the divisions over a wide area under the following classification:

Shenango Group—sandstones and shales.
Meadville Group—sandstones, limestones, and shales.
Oil Lake Group—mostly sandstone and shales.
Venango Oil Sand Group—sandstones and shales.

The whole group has an average thickness in northwestern Pennsylvania of 752 feet.

In Ohio the classification is as follows, according to Prosser (Ohio Geological Survey, Bulletin 15, p. 352):

Logan.
Black Hand.
Cuyahoga.
Sunbury.
Berea.

In the above localities fossil shells are found in these strata so that they can be traced from one section to another and properly correlated, but such fossils are absent in the West Virginia Pocono and plant fossils are only found here and there.

The West Virginia Pocono on account of its isolation from the outcrops in Pennsylvania and from its absence of fossil shells can not be correlated in its subdivisions with those in that State. It is impossible to state whether the divisions of the Pocono correspond to any of the Ohio or Pennsylvania named divisions. In fact, the Pennsylvania geologists who studied the formation further east and southeast were unable to follow any definite terminology for the subdivisions of the Pocono over any large areas in those directions.

The Lower Carboniferous or Mississippian Formations have been studied in great detail in the Mississippi Valley and the name Mississippian is given to them from that locality. The limestones so characteristic of that valley are absent in the East, and the fossil shells of those limestones are not found in the West Virginia Pocono, so that again correlation can not be carried eastward in this formation with any detail though the general relation of the Pocono in time with that of the Mississippi Valley is known. The formations in that valley are divided by Schuchert into the following groups (Bull. Geol. Soc. Amer., Vol. 70, p. 548, 553):

Chesterian.
Meramecian.
Osagian.
Kinderhookian.

According to the correlation of Schuchert, the Chesterian is represented in the East in the Appalachian Area by the Mauch Chunk and Greenbrier, while the Meramecian is probably absent, and the Pocono corresponds to the lower two divisions.

CHAPTER VI.

THE DEVONIAN PERIOD—THE CATSKILL FORMATION.

Below the Carboniferous System of rocks is the Devonian named from its occurrence in Devonshire, England, where it was first studied. In this country the first detailed work on this great system of rocks was carried forward by the geologists of the New York Survey and the names given by them were taken from typical localities of outcrops in that State, and these same names are applied to the divisions of the Devonian throughout this country wherever they can be correlated with the strata in New York. The subdivisions of this system of rocks now recognized are as follows from top to bottom.

Upper...	Catskill..	
	Chemung	(Jennings of U. S. G. Survey publications).
	Portage..	
	Genesee.	
Middle..	Hamilton	(Romney of U. S. G. Survey publications).
	Marcellus	
	Onondaga	
Lower..	Oriskany.	
	Helderberg.	

At the top of the Devonian is the Catskill Formation which is the subject of the present Chapter, and which is to be regarded as a coastal land facies of the Chemung and therefore cotemporaneous with it. The Catskill is composed of red beds, red shales and sandstones mingled with those of green color, practically barren of fossils, and extending in almost unbroken lines from New York to southern West

Virginia. The group was known in the Rogers classification as Formation No. IX, and was named by Vanuxem in New York State, the Catskill, from its great development in the Catskill Mountains of that State, which are described by Lesley as "a lofty table-land of red and gray sandstone and red and gray shale strata lying nearly flat, but turning up along the southern wall with dips of 10, 20, or 30 degrees northwestward; and here supporting remnants of still higher gray sandstone deposits constituting isolated peaks, some of which reach heights of 4,500 feet above tide". The upper gray beds known as the Gray Catskill, according to Lesley, belong in the Pocono.

The formation extends southward across Pennsylvania and Maryland into West Virginia. In western Pennsylvania Lesley states that the Catskill does not come to the surface except in some of the river gaps across anticlinal ridges until it appears as a thin formation in Erie and Crawford Counties and in Ohio, but it is passed through in the various oil wells. According to this same authority, it has been eroded away from the middle of Pennsylvania west of the Susquehanna River except in Perry County and in the deep synclinal trough of Huntingdon, Bedford, and Fulton Counties.

In the northeastern portion of that State, Dr. I. C. White determined the thickness of the Catskill as 1,530 feet, with 375 feet of Catskill-Pocono transition beds. He there named a number of the subdivisions of the Catskill and was able to trace them southward through the counties on the Delaware and Lehigh Rivers. Further away it seemed impossible to follow these divisions with any degree of accuracy. The thickness of the formation in Wayne County was 2,740 feet, and eighty miles west in Tioga County it decreased to 1,940 feet, and 100 miles further west in Venango County, the thickness had decreased to 540 feet, or a decrease of 10 to 14 feet to the mile. In Lycoming County, the thickness was 506 feet.

The formation varies so much in thickness in short distances and the relation of sandstones to shales also varies in short limits that it is usually impossible to carry any detailed correlation of strata of this formation from one area to another. In the northeastern counties of Pennsylvania, there appears to be more regularity and Dr. I. C. White was able to identify certain portions of the section for considerable distances. He found plant remains poorly preserved but no trace of shells. He determined a regular order of certain beds of red shales in relation to certain quarry sandstones, siliceous limestone breccias that seem to have been formed from the wash of some older limestone rock. This section is interesting in its correlation and shows the character of the Catskill in a portion of the State where its sandstones become of economic importance as building stone and it is here reproduced in somewhat condensed form from Dr. White's Report G5, p. 56:

Section of Catskill in Northeastern Pennsylvania (I. C. White).

	Feet.	Feet.
Pocono Sandstones and shales	665	
Catskill-Pocono transition beds	375	
Catskill Strata, proper.		
Mount Pleasant Red Shale		150
Elk Mountain Shales and Sandstone		150
Cherry Ridge Conglomerate		20
Gray shales and sandstone		35
Limestone		5
Red Shale		110
Honesdale Sandstone		90
Montrose Red Shale		180
Paupack Sandstone and shales, red and green		225
New Milford Sandstones		365
New Milford Shales, red and olive		100
Starucca Shale, gray and olive, thin sandstones		105
		1530
Chemung Shales	275	

In Perry County, Claypole estimated the thickness of the Catskill as 6,000 feet, and above, the Pocono measured 2,000 feet. Dr. White secured measurements of 4,500 feet in Northumberland and 4,330 at Catawissa. These measurements seem to represent the greatest thickness of the formation in that State. Lesley states that in Huntingdon, Bedford, and Fulton Counties, on the west, red shale predominates in the upper and middle two-thirds of the formation, while on the east, there is a far greater proportion of gray shales and sandstones than of red.

On Sideling Hill in Huntingdon County, Ashburner measured a detailed section of the Catskill. This ridge is a continuation of the one in the western part of Morgan County, West Virginia, with its associated Catskill beds and shows the characters of the formation further north. It is here given in condensed form from I. C. White's Report, T3, p. 95:

Section of Catskill on Sideling Hill, Pennsylvania (Ashburner).

	Feet.	
Catskill Beds.		
Red shales and sandstones	175	
Red shales, soft and bright alternating with greenish-gray slaty sandstones	100	
Red shales and red flags, alternating with massive shaly yellow-gray and white sandstones	1520	
Red shales, sandy and clayey; lower part ripple-marked and seaweed impressions	270	
Red sandstone, massive and red shale, brown sandstones towards the bottom	140	
Red and gray shales and massive gray sandstones with very small coal seams	290	
Shales, sandy, yellow, with friable red shale and brownish sandstones	60	2680

This section shows a similarity in thickness to the one given below as measured on the west side of Sideling Hill along the Potomac and the character of the rocks of the sections are somewhat similar. The light-brown sandstones occur near the bottom in both sections though the lower green sandstones are not recorded in the northern section.

In Fulton County, Stevenson states that "the Catskill is a mass of shale and sandstone with no definite succession of beds. A section obtained at one locality would be of little service four or five miles away, as the sandstones and shales replace each other suddenly". He also found that the thickness decreased rapidly westward and in the middle of the county on the east side of Sideling Hill "it consisted wholly of soft red shales and occasionally flags of sandstone for 1,600 feet down from its top. Below, brownish or greenish-red sandstones extend down to within 250 feet of the assumed base; then come red and yellow shales". He also found that the sandstones were much cross-bedded and many of them showed pitted surfaces.

In Maryland, Swartz in the State Geological Survey Report on the Devonian (p. 400) states that "in the lower part of the Catskill Formation, the rocks consist of brownish-red sandstones alternating with thick bands of red argillaceous shale, while there are occasional thin bands of greenish shale. . . . . In the upper part of the formation there is a great thickness of greenish-gray sandstone and shale, alternating with red rocks of similar lithological composition. . . . The sandstones are conspicuously micaceous, cross-bedded structure is not infrequent and in some localities there is a rapid horizontal change from sandstone to shale deposits or the reverse." He also states that the thickness of the Catskill in Washington County is about 3800 feet and in the eastern part of Garrett County it is 1800 to 2200 feet.

THE CATSKILL IN MORGAN AND BERKELEY COUNTIES, WEST VIRGINIA.

In Morgan and Berkeley Counties, West Virginia, the Catskill is exposed in several sections in typical exposures. It is composed essentially of green and red sandstones and shales. The green sandstones and light-brown sandstones are characteristic of the lower portion of the formation and they are seen in massive ledges mingled with red sandstone in the cuts of the new lines of the Baltimore and Ohio Railroad at the western side of Morgan County. These sandstones in those fresh exposures are solid ledges of fine-grained, bright-colored strata, with a most durable appearance and have the appearance of a valuable quarry stone. Some of the ledges are hard as granite, but on exposure the green color changes to a greenish-gray and the rock breaks more or less flaggy and shaly, so that it is far from being as durable as it appears to be. The red sandstone varies in color from a deep-brown to a light-brown and to bright-red. It is dotted with minute mica flakes which give the surface a spangled effect. The rock is finely granular and in some cases coarse-grained and occurs in solid ledges which like the green rock soon weathers flaggy and shaly. The new railroad cuts with the alternation of brown, red, and green colored strata give a brilliant picture effect. In the older cuts the same colors persist but less brilliant as a rule and the solid ledges are less common. In the Western Maryland Railroad cuts across the Potomac from Lineburg, there is a succession of green, brown, and red sandstones separated by red and green shales all dipping eastward at rather steep angle and resembling a masonry wall, and here the effects of weathering after a few years' exposure can be studied. The colors have not altered much, but the ledges of sandstone have become quite shaly in many places and some of the shale ledges have crumbled to fine flaky shales and even into clay. The apparently solid ledges of green sandstone when struck with the sledge break into slabs. In places the solid ledges grade into shaly or flaggy shales of the same color. The sandstones vary in the Catskill from solid ledges to flagstones, and the latter seem characteristic of the whole formation.

In the older exposures back from the river in ravines and on county road shales appear to predominate and sectic made in such localities appear to be two-thirds shale, but in such places the flaggy sandstones have weathered into shales and only the most resistant ledges remain and even these are reduced in thickness by the shaly upper portions. Sandstones are thus replaced by shales in short distances, the same as described above in reference to the Catskill in Pennsylvania, so that it is here also impossible to trace the members of the sections any distance across the country. The fresh exposures in the new railroad cuts seem to show that in this area sandstones are the prevailing rocks, and shales only occur here and there through the mass except where they are due to the weathering of a flaggy or shaly sandstone ledge. The original shales of the sections are usually green or red in color, the prevailing color is the red, and the green shales while found in small development in the upper portions of the formation are mainly confined to the lower portions and there are often due to the weathering of the green sandstone. The shales are variable in texture, some are platy solid shales of quite uniform thickness of plates and represent weathered flag-stone. Others are smooth clay shales often a brilliant-red color that break in fine flakes almost free from any visible sand. Others break in concretionary nodules but still in the form of smooth flakes, while others weather to mud balls and apparently represent old mud sediments loosely consolidated; they show no arrangement in parallel beds, breaking irregularly and soon weather to a loose soil or mud. Some of the shales are of bright-green color.

The sandstones are flaggy, nodular, or blocky. Some of these solid blocky ledges are 15 to 20 feet thick unbroken in fresh exposures, and by weathering break into large, more or less cubical blocks. Some ledges are cross-jointed and break down into angular blocks and wedges, while others have a nodular outline. Nearly all show micaceous surfaces, the amount of mica varying in different ledges. The flag sandstones break along these mica planes into large and small slabs with glistening surfaces. In color some of these sandstones are a beautiful brown, fine-grained and hard, while others are of a deep chocolate-brown color. The red sandstone is usually in more broken or flaggy ledges. The soil resulting from the decay of the Catskill rocks is nearly always bright-red and very productive. It is especially adapted to orchard growth resulting in better colored and flavored apples than on the buff shale of the adjacent formations.

Cross-bedding is very characteristic of the group and the oblique stratification is seen in nearly all exposures. It is well developed in the flaggy sandstones and is also observed in the red shales. Ripple-marks are found, but they were not observed in any great number of exposures. Pitted surfaces are seen which probably represent rain-drop impressions. Traces of fossil land-plants, worm-burrows, and rarely fresh-water shells are reported from these rocks, but none was observed in the present study. Mud-cracks were seen in the sandstones of the railroad cuts. Conglomerates are said to be characteristic of the eastern outcrops in Pennsylvania and New York, but were found at only a few places in this area and there poorly developed. Near the north end of the Meadow Branch Valley many concretion-like pebbles, oblong in shape, were found in a ledge of the Catskill. These kidney pebbles were of sandstone and laid down in loose parallel layers in a very loosely cemented mud shale with a thickness of four feet.

At the top of the formation, the Catskill grades into the Pocono so gradually that it is difficult to draw the line between the two groups, and the top was taken in this area at the base of a basal conglomeratic buff sandstone of the Pocono when this was present, as it was in the Sideling Hill outcrops, otherwise it is taken at the base of a heavy ledge of buff sandstone which is regarded as Pocono. At the base, the formation grades without any break into the Chemung olive-green shales, but this line is even harder to locate than the upper limits, as red beds occur through the upper part of the Chemung. Where fossils are present in the Chemung at the top, the line can be drawn more accurately. The base of the Catskill in this Report is placed at the lowest limit of distinctly red beds and the beginning of the buff to greenish shales, but it is a very uncertain line and can only be regarded as approximately correct. Different observers would place the line at different limits and it is probable that no two maps of the area would exactly agree and the measurements of the same sections by different persons would thus vary. The lines of the Catskill as drawn on the maps accompanying this Report are made as nearly correct as possible but at the same time are only approximations of the boundaries, but the error would hardly show on the scale of the present maps.

On account of the variations in sections over the area shales and sandstones not being continuous at any given horizon for any great distance, geological sections are not of much value except to indicate the thickness, and to illustrate this alternation of green and red sandstones and shales. The following section was measured with steel tape along the comparatively recent cuts of the Western Maryland Railroad on the north bank of the Potomac in Maryland nearly opposite Lineburg. The corrections for dip have been made. It is here almost impossible to place the exact line between the Catskill and Chemung, as there is a marked development of red strata in the upper part of the Chemung at this place. In the section this line was placed 2130 feet east of the east portal of the long railroad tunnel. In this interval are 1,830 feet of green and red strata very similar to the Catskill, but this line is continuous with the Chemung to the south of the river and is probably very close to the boundary line between the two formations. The section is as follows:

Section of Catskill on Western Maryland Railroad, North Bank of Potomac River.

	Feet.
Green flag sandstone, solid ledges	187
Green shales, some flag green sandstone	39
Red flaky shales and green flag sandstone	337
Green sandstone	35
Red shales, some ledges red blocky sandstone	244
Green and brown sandstone	35
Red shales	14
Green sandstone and red shales	19
Dark-brown sandstone	85
Dark-brown sandstone and red shales	153
Red blocky sandstone, dark-brown, and red shales	190
Green flaggy sandstone	18
Dark-brown sandstone	72
Red rectangular blocky sandstone	36
Dark-brown sandstone, in large ledges	54
Red shaly sandstone, one green ledge	36
Red shaly sandstone	18
Light-brown blocky sandstone, and red shaly courses	108
Light-brown sandstone and shaly red in alternate ledges	70
Light-brown flaggy sandstone	80
Red shaly sandstone	40
Light-brown sandstone in blocky ledges	32
Red blocky sandstone	40
Light-brown sandstone in thick blocky ledges	32
Shaly and flaggy reddish-brown sandstone	30
Light-brown sandstone in solid ledges	32
Green sandstone in blocky solid ledges	60
Red shaly sandstone	30
Light-brown sandstone in solid ledges	30
Greenish shales, very crumbly	15
Light-brown sandstone in solid ledges	30
Red very shaly sandstone	15
Green very shaly sandstone	15
Light-brown sandstone with six-foot ledge green	15
Shaly red sandstone	65
Light-brown sandstone with some green at top	95
Red and green flaggy sandstone	30
Red blocky and shaly sandstone	35
Light-brown solid ledges sandstone with four feet of green sandstone at top	40
Red shaly and solid ledges sandstone	45
Red shales	32
Red blocky sandstone granular and micaceous	60
Green flaggy sandstone	15
Red shaly sandstone	15

	Feet.	
Red sandstone in solid blocky ledges..............	30	
Red shales......................................	15	
Red and light-brown flaggy sandstone.............	30	
Green shaly sandstone............................	15	
Red shaly sandstone..............................	25	
Red shaly sandstone and green flaggy sandstone...	24	
Light-brown sandstone, shaly green below.........	22	
Green flaggy sandstone...........................	35	
Red sandstone in solid blocky ledges..............	45	
Green flaggy sandstone...........................	57	
Green and red shaly sandstone, mixed and contorted	70	
Red solid sandstone weathers shaly...............	25	
Dark-brown sandstone.............................	10	
Red shaly sandstone..............................	35	3116

Series of red and green shaly and flaggy sandstones, red shales, show ripple-marks and represent either Chemung or transition beds..............1830 feet.

If the red and green beds to the west to the tunnel portal are included, the thickness would reach 4,946 feet, or almost 5,000 feet, which is too large when compared with the adjoining sections to the south and southeast, so that the thickness of 3,116 feet is probably very nearly correct.

While to the south and east the green sandstones are apparently more common in the basal portions of the sections, they are seen in the above section to occur all through the formation from the bottom to the top. In the upper third of the series, there are 306 feet of green sandstone and shale, 218 feet in the bottom third, and 80 feet in the middle portion, or a total of 604 feet, about one-fifth of the total thickness. The amount of red shales is 453 feet, or about one-seventh, though in addition there are numerous beds of shaly red sandstone that weather to shales in long exposures.

The above section may be condensed into the following groups:

	Feet.	
Green sandstones and red shales or shaly sandstone	910	
Dark-brown sandstone, and red shales, or shaly sandstone	762	
Light-brown sandstone, red shales, or shaly sandstone and some green sandstones.............	839	
Red and green sandstones and shales.............	605	3116

A partial section of 1,035 feet was measured on the east limb of the syncline one and a half miles south of Sleepy Creek

Station, and 75 per cent. of the series was red shale. The rocks are here exposed in a deep ravine and have been subjected to a long period of weathering, so that the shaly and flaggy ledges have broken down into shales. The more resistant ledges remain, some of which have a thickness of 35 to 40 feet. Nearly all the sections further south show this same predominance of shales, but the fresh railroad cut exposures show that shale is not the predominant rock of the series in this area, but on account of their soft non-resistant nature they soon grade into the shales.

The thickness of the Catskill Formation east of Third Hill Mountain opposite Hedges Mountain was calculated to be 3,757 feet; on the west limb of the syncline north of Meadow Branch Mountains, or one and a half miles south of Sleepy Creek Station, it is 3,537 feet; and on the east limb of this same syncline it is 3,000 feet. West of Woodmont the thickness was determined as 2,495 feet. East of Orleans Crossroads and up Sideling Hill it was 3,200 feet. But in this section the base of the Catskill is very difficult to separate from the Chemung and some of the latter beds may be included, though this figure agrees with the section measured on the Western Maryland Railroad about two miles north, which is given in the above detailed section as 3,116 feet.

The thickness thus decreases from east of Third Hill Mountain to Orleans Road, 557 feet in a distance of fourteen miles, or about 40 feet to the mile. Martin in the Maryland Geological Survey Report on Garrett County determined the thickness of the Catskill in the eastern portion of that county as 1,800 to 2,200 feet, which would represent an average of 2,000 feet, and this point is 40 miles west of Orleans Road, a decrease in thickness of 30 feet to the mile. He determined the thickness in the western part of Garrett County to be 1,200 to 1,400 feet, or a decrease of 600 to 800 feet in a distance of about twenty miles, or 25 feet to the mile.

Hennen measured a section of the Catskill at Rowlesburg in Preston County, West Virginia, and determined the thickness to be 601 feet. This would represent a decrease of 700 feet from the section in western Garrett County, fourteen miles east, or 50 feet to the mile. The decrease in thickness from

Orleans Road to Rowlesburg is 2,600 feet, and the distance is 70 miles south of west, or an average decrease in thickness for the whole distance of 37 feet to the mile.

In Pennsylvania, according to Professor Stevenson, the thickness of the Catskill decreases from 3,700 feet in Fulton County to 1,980 feet in western Bedford, 35 miles distant, or 50 feet to the mile.

Hennen in his Preston County Report of the West Virginia Geological Survey (p. 100) gives a section of the Catskill Formation near Rowlesburg which is here given in a condensed form:

Section of Catskill at Rowlesburg, Preston County (Hennen).

	Feet.	
Red shale	10	
Sandstone, massive	60	
Sandstone, gray, hard, micaceous	38	
Red shale and shaly sandstone	44	
Sandstone, massive, reddish-gray	56	
Red shale and shaly sandstone	40	
Sandstone, green, micaceous, and red shales	63	
Red shales and thin sandstones	50	
Red shales and sandstones alternating	196	
Sandstone, green, brown, fine	25	
Red shales	8	601

Chemung Series.

This section shows a similar alternation of red shales and sandstones to the sections further east in Morgan and Berkeley Counties. It shows the presence of green sandstones but they are small in total amount and found near the middle of the section and at the base.

The oil wells in the central and western portions of West Virginia are in many places drilled into and through the Catskill beds and a number of paying sands are known in that series. Near the top are the Gantz and "Fifty-foot" Sands, 50 to 100 feet thick, and described by Dr. I. C. White as coarse, pebbly, solid sandstones in Monongalia and Marion Counties. In this series also comes the "Thirty-foot" gas Sand, and the Gordon Sand, in which Dr. White states the largest and most productive oil wells have been found. In this series is the McDonald or "Fifth Oil Sand" of Pennsylvania, which is a gas sand near Weston and Clarksburg; also the Bayard or "Sixth" Sand, a gas and oil sand 5 to 25 feet thick and very productive in portions of Monongalia and Marion Counties.

In Taylor County the well records show a thickness of 560 feet of Catskill beds; near Morgantown, 480 to 504 feet; in Harrison County, 420 to 560 feet; in Wetzel County, 410 feet; and in Greene County, Pennsylvania, 396 feet. The distance from Rowlesburg, where Hennen measured the Catskill as 601 feet thick, to Wetzel County, where the thickness is 410 feet, is 45 miles with a decrease in thickness of 190 feet or about four feet to the mile. The variation in thickness of the Catskill from central West Virginia west in the oil fields is not large. In fact there is quite a uniformity in the thickness in this belt and the average thickness is around 550 feet.

OUTCROPS.—The **Catskill Rocks** outcrop in four areas in Morgan and Berkeley Counties, on each side of the Purslane-Sideling Hill Mountain, and on both sides of the Meadow Branch Mountains. At the west side of Purslane Mountain, the red rocks of the Catskill extend across Morgan County southwest to northeast in a belt three-fourths to two and a half miles wide extending up the slope of the mountain to a height of 1300 to 1500 feet above tide, or about 800 to 1000 feet above the Potomac level. Near the top it is covered by the Pocono beds. On the west it extends to the river valley and the eastern bends of the river are cut into it. The formation there grades into the Chemung Shales so that it is impossible to accurately separate the two groups. Stose from his studies of this area (Pawpaw-Hancock Folio) separated about 500 feet thickness of these beds on this border line which he marked as the Catskill-Jennings (Chemung) transition beds, thus separating them from the regular Catskill. Along this western edge the basal beds are green and red sandstones well exposed in the new cuts of the railroad. Eastward toward the mountain, the formation is composed of red shales and red solid and flaggy sandstones. The sandstone weathers to shales so that over this weathered zone the prevailing rock exposed is shale. The runs have cut deep valley gorges in than five feet thick; and yet it makes a bolder show than its rival on the opposite hill; for where the rock itself does not project from the surface a straight line of piled up fragments traverses the fields of shale. Every road crossing Allegrippus Ridge as far as the Bedford line shows it plainly; and, as has been already said, in Bedford and Fulton Counties the Chemung ridges are crested with it in a like, or even in a superior manner."

While Dr. White correlated these two conglomerates with the Upper and Lower Conglomerates of the Fulton County sections, C. S. Prosser regards the evidence as insufficient for this correlation, but believes there is some probability that the Upper Conglomerate of that county may be represented by the Lower Conglomerate of the Garrett County, Maryland, sections.

The upper portion of the Upper Devonian beds of Maryland were regarded by Professor Prosser as Chemung and he thus describes them (Md. Geol. Survey, Report on Upper Devonian, p. 348):

"The upper part of the Jennings Formation consists of argillaceous and arenaceous shales alternating with beds of sandstone which are often micaceous, while several layers of conglomerate occur in this member. These shales and sandstones are usually greenish or greenish-gray in color and weather to a yellowish-green, but there are not infrequent zones of brownish-red shales and sandstones. In certain layers fossils are common and the characteristic species, *Spirifer disjunctus* Sowerby of Chemung stage, occurs frequently and this together with the presence of other Chemung species, lithological similarity and stratigraphic position indicates the correctness of the correlation of this division with the Chemung stage of New York."

In the work of the Maryland Survey on the Devonian (p. 419) Swartz recognized five subdivisions of the Chemung beds as follows:

Chemung.
- Upper shale and sandstone beds.
- Upper conglomeratic sandstone beds.
- Middle shale and sandstone beds.
- Lower conglomerate sandstone beds.
- Lower shale and sandstone beds.

When this grouping of the strata is compared with Professor Stevenson's grouping of the Pennsylvania sections and south to New River, as given above, it is found to be the same.

PLATE XIII(A).—Hamilton Shales with Blocky Ledges above, and Finely Laminated below, Low Grade Railroad Cut along Potomac.

PLATE XIII(B)—Chemung Shales with Blocky Sandstone Ledges in Baltimore and Ohio Railroad Cut west of Hansrote.

neighboring portions of Maryland (Pawpaw-Hancock Folio, p. 92):

Spirifer disjunctus.
Spirifer (Delthyris) mesacostalis.
Spirifer mesastrialis.
Douvillina cayuta.
Productella lachrymosa.
Camarotocchia contracta.
Ambocoelia umbonata.
Chonetes scitulus.
Pterinea chemungensis.

CHEMUNG GEOLOGICAL SECTIONS.

In order to illustrate the character of the rocks of the Chemung in this area, two sections measured by Professor Swartz in Maryland across the Potomac from the Morgan County area, and given by him in the Maryland Survey Report on the Upper Devonian (pp. 458-459 and 482-486) are here quoted, the first section being measured on the National Road east of Hancock:

Chemung Section East of Hancock, Maryland (Swartz).

	Feet.	
Jennings-Catskill contact.		
Concealed	322	
Yellow shale poorly exposed, fossiliferous near top	95	
Dark red shale	15	
Brown shale, weathering yellow-green	15	
Dark red shale	8	
Argillaceous yellow and green shale	15	
Arenaceous chocolate-red shale	7	
Argillaceous chocolate-brown sandstone	21	
Chocolate-red shale	17	
Dark yellow shale	34	
Dark purple sandstone	1	
Arenaceous shale	25	
Dark purple sandstone one foot, chocolate-brown shale	18	
Argillaceous sandstone, and shale, at top, *Spirifer mesastrialis* abundant	4	
Concealed, massive conglomeratic sandstone at top, 20 feet thick	322	
Concealed, massive gray sandstone at top	150	
Concealed, some massive conglomerate shows, also *Spirifer disjunctus* found	702	
Argillaceous shale and some sandstone, near top the fossil *Ambocoelia umbonata* abundant	10	
Largely concealed, argillaceous sandstone and shale fossil *Chonetes scitulus*	254	2035
Parkhead Sandstone		

Professor Swartz measured another section of the Chemung near the State Line in Fulton County, Pennsylvania, and found the thickness to be 2604 feet, and two miles west of Pawpaw, he measured a very complete section of the Jennings where the Chemung beds had a thickness of 2717 feet.

Professor Swartz gives in the Maryland Survey Report on the Upper Devonian a number of detailed and interesting sections of these formations and one more will be quoted in somewhat condensed form which was measured by him at Little Orleans, Maryland, which is across the river from Orleans Crossroads, a town on the Baltimore and Ohio Railroad in the western part of Morgan County. He there obtained very fresh exposures in the comparatively new cuts of the Western Maryland Railroad:

Chemung Section near Little Orleans, Maryland (Swartz).

Jennings-Catskill contact.	Feet.
Green and brown sandstones	73.2
Brown and green shale, breaking irregularly	25.3
Brown and green sandstones with interbedded shales	162.8
Brown hackly sandstone and thin-bedded green sandstone with interbedded green shale	108.7
Massive brown and gray sandstones	65.4
Red flaggy sandstone and red shales	18.5
Brown and green shales and brown and gray sandstones	123.1
Brilliant red hackly shale	12.3
Green and brown shales and brown sandstone	132.8
Thin-bedded gray flaggy sandstone	63.7
Brown and green hackly shales some sandy shale	47.9
Brown sandstone and hackly brown and green shales	112.6
Red and green shales with thin beds of sandstone	65.2
Heavy and thin-bedded gray sandstone, coarse-grained, carrying small pebbles	12.2
Brown and gray sandstones with reddish-brown and green shales	93.2
Conglomeratic sandstone, 9 inches conglomerate at top	12.2
Green and grayish-green shales and sandstones	272.3
Olive-green shales and gray flaggy sandstone	117.2
Reddish-brown and green shales and sandstones	317.7
Conglomeratic grayish-brown sandstone	1.6
Grayish-green shales and sandstones	89.4

	Feet.	
Grayish-brown shales and brown sandstone.....	108.1	
Grayish shales and sandstone..................	187.3	
Grayish-green sandy shales and gray sandstones.	137.5	
Grayish-brown sandy shales and sandstones....	65.2	
Thin-bedded green shales and gray flaggy sandstone	105.3	
Thin-bedded grayish-green shale somewhat fissile and sandy, with some beds of six-inch thick sandstone...........................	18.1	2548.8
Parkhead Sandstone..........................		

On the West Virginia side it is impossible to secure such complete sections and this Maryland section may be taken as representative of the Chemung in the western part of Morgan County as well. In this section, a 12-foot conglomerate is found 1012 feet below the top, and a foot and a half conglomerate 800 feet lower. These intervals are somewhat similar to those in the Fulton County section of Stevenson quoted above. In the section west of Pawpaw given by Swartz in the Maryland volume, the Upper Conglomerate is 1320 feet from the top and the Lower Conglomerate is 844 feet below, which would suggest their correlation with the Fulton County Conglomerates which were correlated by Dr. I. C. White with his Upper or Lackawaxen Conglomerate and the Lower with his Allegrippus Conglomerate. In the section quoted above from east of Hancock, the Upper Conglomerate was found 1362 feet below the top of the Chemung.

The following section of the Chemung was measured two miles south of the river from Woodmont, along the county road that crosses the formations westward, in ascending order:

Chemung Section Two Miles South of Woodmont, Morgan County.

	Feet.
Parkhead Sandstone.	
Reddish-buff shales..............................	100
Partly concealed, ash-gray soil, at top nodular sandstone blocks................................	60
Pearl-gray shales................................	15
Sandy shale, glistening, some buff flaky............	50
Gray sandstone..................................	2
Light-buff flaky shales............................	270

	Feet.	
Chocolate-brown shales	15	
Solid ledge blocky sandy shale	15	
Coarse buff sandstone	12	
Buff shales, irregular nodular and some buff sandstone ledges	120	
Small flaggy sandstone blocks	8	
Buff flaky and nodular shales	30	
Fine sandy shales in small flakes and plates	150	
Blocky sandstone ledge	10	
Buff platy shales	40	
Blocky red sandstone	5	
Buff shales	30	
Chocolate-brown shaly sandstone	8	
Blocky shales	20	
Chocolate-brown shales	15	
Buff shales, blocks brown sandstone	40	
Buff and reddish-buff shales	25	
Brown sandstone and conglomerate, some shales	25	
Concealed and sandy shales	307	
Buff sandy shales, thin ledges shaly sandstone	90	
Reddish shales	74	
Buff sandy shales	80	
Blocky buff sandstone	24	
Reddish and buff shales	22	
Red shaly sandstone	20	
Sandy shales	36	
Shaly sandstone ledge	8	
Red and buff shales	95	
Red shales	100	
Shaly flaggy sandstone	22	
Red sandy shales	28	
Blocky red sandstone ledges	70	
Shaly sandstone and shales to bed of run	76	2117

This section shows a grouping of sandy shales and sandstones with one conglomerate ledge noted 1,040 feet from the bottom, or 1,077 feet from the top, which is similar to the interval to the Upper Conglomerate in the Fulton County Pennsylvania, and the Orleans, Maryland, sections, and this is probably the same horizon and represents the Upper Conglomerate of Stevenson and possibly the Lackawaxen of White. The other conglomerate was concealed in this section, and the fossil ledges were not located.

The section back of Woodmont shows only 1712 feet of Chemung and is probably incomplete, though nearly the same thickness was found in a section two miles west of Cherry Run.

OUTCROPS.—The Chemung beds have been mapped using the top of the Parkhead Sandstone as the base, and as thus limited, they are found in several northeast-southwest belts across Morgan and Berkeley Counties.

At the extreme western side of Morgan County on the narrow tongues of land formed by the westward bends of the Potomac, the shales of the Jennings Group are thrown into a series of folds from which the tops have been eroded leaving synclinal troughs of Chemung strata and anticlinal folds of Portage. The narrow synclinal belt of Chemung shales is seen about the middle of the westward bend one mile west of Doe Gully, and again about the same distance west of Hansrote. At the extreme western ends of these river peninsulas are small portions of Chemung connected with the Maryland areas across the river. The rocks are shaly sandstones and shales more or less tinged reddish to brown.

A belt of Chemung follows the eastern side of the river bends bordering the Catskill and extends across the county with a width of one-half to three-fourths mile. This belt is closely associated with the red beds of the Catskill and can not be accurately separated from that formation so that in the United States Geological Survey Folio on this district, a belt has been marked between the two formations and called the Jennings-Catskill transition beds with an average thickness of 500 feet. In the maps with this Report most of this area was included with the Catskill. It would require fossils to determine the proper line between the two formations and none was found in the present field work.

A belt of Chemung extends across the county east of the Catskill area east of Sideling Hill, reaching the Potomac in the vicinity of Woodmont Station, with a width of about one-half mile through the whole length.

A broad synclinal belt of Chemung follows northeast-southwest across Morgan County about one mile east of Berkeley Springs or Warm Spring Ridge. This area opposite and to the south of Berkeley Springs is about one mile wide, increasing toward the north to two miles. It is divided at the north near the Potomac into two parts by an anticlinal mass of Catskill that projects into the State from Maryland. About eight miles south of Berkeley Springs near Stotlers Cross-roads, this belt extends eastward around the southern end of an eroded anticlinal fold of Portage rocks and joins the Sleepy Creek Chemung area.

The Sleepy Creek Chemung belt to the west of the Catskill west of Sleepy Creek Mountain extends along the west side of the creek from New Hope north, and follows the east side of the creek south of that place. Its width is about a half mile and near the Potomac it is connected with the area east of the mountains.

The belt of Chemung rocks east of the Catskill area east of Third Hill Mountain has a width of less than a half mile and at the north end near the Potomac bends to the west and connects with the preceding area making a broad but narrow belt at that place.

The thickness of the Chemung beds varies from 1712 feet near Woodmont to 2117 feet two miles south, and appears to be about 2800 feet eight miles south near Fishers Ford. The belt east of Third Hill Mountain and two miles south of the river has a thickness of 1752 feet. The Orleans section in Maryland quoted above would indicate the thickness in the western portion of Morgan County to be 2548 feet. Stose in the Government Folio states that the thickness of the beds above the Parkhead Sandstone is 1500 to 2300 feet, in this area.

THE PORTAGE FORMATION.

The Portage Formation, according to Lesley (loc. cit., p. 1337), was named in western New York from the village of that name, which was so named "from the three high falls of the Genesee River, which impeded its navigation, compelling the Indians to carry their canoes from the higher to the lower level, or *vice versa*, and the engineers of the Erie Canal to construct a staircase of locks". Here the whole formation, 1000 feet thick, is exposed. It carries no Chemung fossils and was made a separate formation, but in a large part of Pennsylvania, Lesley states that both the Chemung and Portage have a much greater thickness and closer resemblance so that they can not be separated. He further finds that the Portage in

Pennsylvania has the fossils confined to a few of the beds so that it is often described as non-fossiliferous in marked contrast to the beds above and below it.

In Huntingdon County, Dr. I. C. White estimated the combined thickness of the Chemung and Portage as 2650 feet (T3, p. 99), divided into upper more massive gray sandstones of Chemung age, 1500 to 1600 feet; and lower yellowish sandy and shaly sandstones of the Portage, 1000 to 1100 feet. In Fulton County, Professor Stevenson separated the Portage with a total thickness of 3620 feet, but in Bedford County, he included both under the Chemung and states it was not possible there to make a separation.

In Maryland, Professor Swartz divides the lower Jennings into two groups as follows (loc. cit., p. 411):

Parkhead Sandstone member.
- Shale beds.
- Conglomerate sandstone beds.

Woodmont Shale member.
- Beds containing Ithaca fauna.
- Beds containing Naples fauna.

The Parkhead Sandstone was named from Parkhead Station on the Western Maryland Railroad in Maryland one and a half miles east of Sleepy Creek Station in West Virginia. It is there found in typical exposure and is thus described by Swartz in the Maryland Survey Report on the Upper Devonian (p. 415):

"It consists of shale interbedded with massive, frequent conglomeratic sandstones. Certain beds of the latter are highly fossiliferous at many places. The shale is more arenaceous than that of the Woodmont member and tends to break more irregularly. When freshly exposed, the strata vary in color from gray to olive-green, while some beds are nearly black. Upon weathering they usually become yellowish or buff in color. The thickness varies from 400 feet, in the eastern exposures, to 800 feet, west of Green Ridge."

This member in Maryland shows two well-marked divisions, a lower conglomeratic sandstone group with conglomcrates at base, near the middle, and at the top, with a total thickness of 400 feet in the eastern sections. Swartz found the lower sandstone or conglomerate usually rich in fossils and lists the following (Pawpaw-Hancock Folio, p. 90) which he states have a marked Hamilton aspect:

Tropidoleptus carinatus.
Spirifer (Delthyris) mesacostalis.
Spirifer marcyi var.
Camarotoechia congregata var.
Productella lachrymosa.
Cyrtina hamiltonensis.
Cypricardella bellistriata.
Coleolus tenuicinctus.
Pleurotomaria capillaria.
Diaphorastoma lineatum.
Many other species of
Platyceras, Cyclonema, Bellerophon, etc.

Professor Swartz, from his very detailed and careful comparative study of the fauna of the Parkhead, reaches the following conclusion on the correlation of this member (p. 90):

"This fauna occupies a stratigraphic position similar to that of the Enfield fauna, described by H. S. Williams, which occurs in the upper part of the Portage Formation of New York overlying the Ithaca shale member, and with which it is provisionally correlated. Its Hamilton aspect is marked. Like the Enfield fauna of New York, it occurs in beds older than those containing the Chemung fauna in this section and is therefore classified with the Portage faunas. Because of the prevailingly sandy character of the rocks of this member, which closely resemble and grade into the overlying strata containing the characteristic Chemung fauna, they are placed by many at the base of the Chemung Formation, as has been done by Williams."

The upper part of the Parkhead member consists of shale and sandstone ledges, and is only slightly fossiliferous.

Below the Parkhead is the **Woodmont Shale,** named from that station on the Western Maryland Railroad opposite the station of same name in West Virginia one and a half miles west of Sleepy Creek. It was named by Swartz, who describes it (Md. Geol. Survey, Devonian Report, p. 413) as follows:

"It consists of alternating courses of olive-green shale and thin, fine-grained, flaggy sandstone, with an occasional more massive sandstone. The shale is usually fissile and breaks into smooth thin fragments with parallel sides, contrasting strongly in this respect with the very irregular fragments produced by the weathering of the underlying Romney. Some of the upper beds are more arenaceous and fracture irregularly. Upon weathering the shale becomes greenish or yellowish. A few beds have a decided reddish-brown color. The sandstone is prevailingly micaceous and usually becomes fissile on weathering, breaking into platy fragments. Occasionally a sandstone is more massive and breaks into larger, irregular fragments. The surface of the shale often exhibits 'dimpling' and indistinct wave

markings. The strata of this member usually occupy the lower slopes of the ridges formed by the more resistant sandstone of the Parkhead member. The thickness varies from 1600 feet in the eastern sections to 1200 or 1300 feet in the sections west of Green Ridge."

According to Swartz, the lower beds of the Woodmont member contain a fauna similar to that of the Naples in New York with a thickness at the east of about 500 feet, increasing west of Green Ridge to 1300 feet, and the rocks are mostly olive-green shale with some thin flaggy sandstones. Above the beds with the Naples fauna is a series of shales with but few thin sandstone ledges which contain a fauna similar to the Ithaca of New York. Swartz states that the thickness of the Ithaca fauna beds near Hancock is 1000 to 1100 feet and gives the following list of the more abundant species (Pawpaw-Hancock Folio, p. 88):

Spirifer mucronatus var. *posterus*.
Productella speciosa.
Reticularia laevis.
Leiorhynchus globuliforme.
Schizophoria striatula.
Cyrtina hamiltonensis.
Pugnax pugnus var. *altus.*
Stropheodonta demissa.
Atrypa reticularis.
Ectenodesma birostratum.
Cladochonus sp.

According to Professor Swartz, "the species characteristic of this fauna occur also in the Ithaca fauna of the Portage Formation of New York, where they occupy a similar stratigraphic position."

Professor Prosser (Maryland Geol. Survey, Report on Upper Devonian, p. 348) reached the same conclusion as to the correlation of these beds with the Portage of New York, and states:

"The writer correlated the beds between the top of the Genesee shale, or when this shale is absent the top of the Romney, and the lowest ones containing *Spirifer disjunctus* Sowerby, with the Portage of New York."

PORTAGE GEOLOGICAL SECTIONS.

Professor Swartz, in connection with his studies of the Maryland Devonian, made two very detailed sections in West Virginia east of Berkeley Springs. On account of his knowledge of this fauna, these sections are so complete and represent so carefully the rock and faunal characters of the formations that they are here reproduced in complete sections from his Maryland Geological Survey Report on the Upper Devonian (pp. 452-457). The first section was made on Yellow Springs Run three miles east of town:

Section of Portage Formation Three Miles East of Berkeley Springs (Swartz).

	Feet.
Parkhead Sandstone Member.	
Concealed. At top a massive brown conglomerate exposed	190
Concealed in part. A massive brown sandstone 20 feet near the center	77.8
Smooth green shale	24.5
Green shale breaking into irregular fragments. A brown conglomeratic sandstone 15 inches thick at base of unit	12.2
Smooth green shale	38.5
Arenaceous shale breaking irregularly	4.5
Green shale breaking irregularly	16
Green shale breaking irregularly. Thin beds of fine-grained sandstone on top. At the bottom of this unit occurs a conglomeratic sandstone containing *Camarotoechia congregata* var. *parkheadensis* abundant, and *Spirifer mesacostalis* abundant	21.5
	385.0
Woodmont Shale Member. Ithaca Fauna Beds.	
Arenaceous shale and sandstone of deep-red color	28.9
Green shale	108
Red shale breaking irregularly	31.7
Red shale and hard red sandstone	65.1
Green sandstone and shale	7.6
Fissile green shale	45.6
Red shale breaking irregularly	8.3
Green and red shale	26
Coarse shale, irregular fracture, red and green sandstones	7.6
Green and red shale and sandstone	26.8
Concealed	22.8
Green fissile shale. At the bottom were found *Cyrtina hamiltonensis, Leiorhynchus globuliforme, Productella speciosa.* all abundant, also *Spirifer mucronatus* var. *posterus*	50
Red and green shale breaking irregularly	22.6
Coarse green shale containing at bottom the same fossils as above and *Grammysia communis*	15
Green and brown shale breaking irregularly and some sandstone. At the bottom occur *Productella speciosa, Schizophoria striatula, Spirifer mesastrialis, S. mucronatus* var. *posterus* abundant	69
	526.0

East of this point the folding is too intricate to permit the determination of thickness.

The next section quoted from Professor Swartz's report was made just east of the town of Berkeley Springs from the Romney contact eastward for a horizontal distance of 3284 feet. In describing this section, he states that "it is admirably exposed, free from minor folds, rich in fossils, is the most satisfactory section for the correlation of the lower strata of the Jennings observed in the eastern part of the area studied."

Section of Portage Formations just East of Berkeley Springs (Swartz).

	Feet.
Parkhead Sandstone Member.	
Concealed. A massive brown conglomerate sandstone at top, 15 feet thick	27
Concealed. A massive gray sandstone at top 12 feet thick, containing *Camarotoechia congregata* var. *parkheadensis, Tropidoleptus carinatus, Spirifer mesacostalis*	177.2
Concealed in part, exposing some fissile olive-green shale	127.5
Massive greenish-gray sandstone, with *Camarotoechia congregata* var. *parkheadensis* abundant, *C. congregata* with deeper sinus suggesting var. *contracta, Spirifer mesacostalis, Cypricardella gregaria* var., *Cyclonema multistriata.* Thickness approximate	12
	343.7
Woodmont Shale Member. Beds with Ithaca Fauna.	
Very red shale having a bed of green sandstone 18 inches thick at bottom	30
Fissile olive-green shale	39
Olive-green shale breaking irregularly	6
Fissile olive-green shale	30
Red shale	18
Concealed	9
Green sandstone	12
Fissile brown shale	24
Massive brown sandstone	3
Red shale	12
Red shale containing at top *Productella speciosa, Schizophoria striatula, Spirifer mucronatus* var. *posterus,* first and last abundant	12
Fissile green shale	43.6
Fissile red shale	11
Olive-green shale with thin beds green sandstone	69
Olive-green shale of varied physical character	72.7
Hackly green shale and a few thin beds of brown shale with the following fossils at top: *Cyrtina hamil-*	

	Feet.
tonensis, Productella speciosa, Pugnax pugnus var. *altus*, all abundant, *Leiorhynchus globuliforme, Spirifer mucronatus* var. *posterus*......................	69.1
Brown shale and sandstone..........................	13.5
Hackly green shale containing at top the above fossils and also *Schizophoria striatula* and crinoid rings....	6
Green shale breaking irregularly, with *Productella speciosa* common and *Spirifer mucronatus* var. *posterus Palaeoneilo brevis?*..........................	10.5
Green hackly arenaceous shale with *Productella speciosa* abundant at top................................	6
Green hackly shale and thin beds of fine-grained green sandstone. At top occur *Pugnax pugnus* var. *altus, Lingula statulata, Leiorhynchus globuliforme, Schizophoria striatula, Productella speciosa, Spirifer mucronatus* var. *posterus*..........................	47.5
Green shale very fissile at bottom, becoming gradually more hackly above with *Spirifer mucronatus* var. *posterus* at top..................................	185
Green shale of varied character with *Cladochonus humilis* abundant at top...........................	39
Hackly green shale, one bed chocolate colored, with *Atrypa reticularis, Schizophoria striatula* common....	14.1
Arenaceous green shale breaking irregularly..........	17.5
Green shale breaking irregularly with fossils at top: *Cladochonus humilis, Atrypa reticularis, Productella speciosa, Reticularia laevis Spirifer mucronatus* var. *posterus*	10.5
Fissile green shale..................................	32
Fissile olive-green shale and thin beds of green sandstone with following fossils at top: *Atrypa reticularis* abundant, *Lingula spatulata, Leiorhynchus globuliforme* common, *Reticularis laevis* abundant, *Spirifer mucronatus* var. *posterus, Stropheodonta demissa* common	89
Beds With the Naples Fauna.	
Concealed	91.5
Largely concealed but indications that strata similar to the following unit except that sandstone beds are more numerous................................	243
Fissile olive-green shale interbedded with thin layers of flaggy sandstone, with crinoid segments at top..	126
Fissile olive-green shale............................	74.3
Largely concealed....................................	88.5
Romney-Jennings contact.	
	1554.3
Total thickness of Portage beds..............1898 feet.	

In Morgan and Berkeley Counties, the Parkhead horizon is marked by an outcrop of brownish sandstone and hard vitreous conglomerate forming ridges which can be traced across the county, but the shales have weathered and the sandstone debris partially conceals them so that it is usually very difficult to obtain any complete sections of this formation. The following sections show the character of the rocks composing the Woodmont Shale member of the Portage in this area and the thickness of the Parkhead member has been estimated from width of outcrop of the sandstones and shales composing this member as far as it was possible to locate them.

The following section was measured to the east of Woodmont Station one mile west of Sleepy Creek Station along the county road:

Section of Portage East of Woodmont, Morgan County.

	Feet.
Parkhead Sandstone and shales.	
Greenish-buff shales	55
Red shales	6
Flaggy greenish-gray sandstone, smooth plates	12
Buff shales	30
Flaggy sandstone	8
Buff shales, some red	36
Concealed, mostly greenish-buff shales	220
Reddish and buff blocky shales	75
Olive-green shales	130
Greenish-buff flaky and blocky shales	50
Greenish-buff shales	106
Concealed, a gravel-covered terrace	105
Greenish-gray and red and buff shales with blocks of green sandstone	415
	1248
Romney Sandstone.	
Parkhead, estimated	475
Total thickness Portage	1723

Another section of the Woodmont member of the Portage was measured eight miles south of Woodmont and west of Fishers Ford, as follows:

Section of Portage West of Fishers Ford, Morgan County.

	Feet.
Parkhead Sandstone and shales.	
Platy buff and flaky shales	75
Greenish compact smooth shales	130
Blocky greenish-buff sandstone	2
Olive-green smooth shales	156

	Feet.	
Reddish and buff shales weather to small blocks or flakes like a sand	75	
Greenish small blocky shale	75	
Smooth green platy shales and at top a thin ledge of greenish flag sandstone	315	
Green sandstone part of it solid and compact, and hard shales or flag sandstone	180	
Platy greenish shales and buff	284	1292
Greenish-gray hard sandstone of Romney. Parkhead member, estimated		480
Total thickness of Portage		1772

About half-way between these two sections, the Woodmont member was measured as 1260 feet.

OUTCROPS.—The Portage Formation with its Woodmont and Parkhead members is found in two eroded anticlinal belts separated by a synclinal trough of Chemung in the westward bends of the Potomac west of Doe Gully and Hansrote along the western edge of Morgan County.

A belt can be traced northeast-southwest across Morgan County just west of the Romney belt west of Tonoloway Ridge in the same county. The Parkhead Sandstone and conglomerate forms at this place Road Ridge while the Woodmont Shales and thin sandstones are found on the eastern slope of this ridge in a belt about 1000 feet wide.

A somewhat wider belt of Portage rocks follows parallel to the east side of Warm Spring Ridge, passing east of Berkeley Springs to the Potomac near Hancock. The Parkhead here forms the crest of Horse Ridge.

Two miles east of Berkeley Springs from Riderville to Sleepy Creek and south, is an anticlinal fold of Portage rocks which is covered by the Chemung at the south just north of Stotlers Crossroads, but it extends northward to the river. North of Stohrs Crossroads the Woodmont member has nearly disappeared until it comes in again about a mile south of the river.

In northeastern Morgan County and the western portion of Berkeley, a long narrow belt of Portage is found about one and a half miles east of Third Hill Mountain and parallel with it. The Parkhead here forms the crests of a series of ridge hills with the Woodmont on the eastern slope.

A narrow anticlinal area of Portage extends from the Hedgesville road one-half mile west of the town, northeast to the river bluffs on the low-grade line of the Baltimore and Ohio Railroad.

THE GENESEE BLACK SHALES.

The basal member of the Upper Devonian is the Genesee, which includes a group of fissile black shales that rest upon the Hamilton Sandstones and grade upward into the Portage beds. The Portage Shales are olive-green in color and break into irregular-shaped fragments while the Genesee Shales are black to brownish and break into smooth plates.

Swartz states in the Pawpaw-Hancock Folio (p. 86) that:

"This member is about 100 feet thick a short distance west of the Pawpaw Quadrangle. It is exposed in the Pawpaw Quadrangle only on a small anticline that enters the quadrangle west of Green Ridge (Maryland), where it is but a few feet thick, its precise thickness not being determinable, but it is too thin to be mapped. It thins and disappears in a short distance eastward. The Genesee black shale member abounds in individuals of a few species wherever its strata are exposed. The fossils are chiefly minute pelecypods associated with pteropods and goniatites."

The fossils found are similar to those of the Genesee of New York and Swartz states that the eastward disappearance is a feature also observed in the formation in New York. This formation is not exposed in the eastern Panhandle Counties.

PLATE XIV(A).—Hamilton Shales contorted around a Sandy Inclusion, Low Grade Railroad on Potomac.

PLATE XIV(B).—Hamilton Shales Showing Spheroidal Weathering near Mouth of Back Creek.

CHAPTER VIII.

THE DEVONIAN PERIOD—THE HAMILTON, MARCELLUS AND ONONDAGA FORMATIONS.

The Middle Devonian Group in West Virginia is represented by the following formations:

Hamilton.
Marcellus.
Onondaga.

Darton of the United States Geological Survey in 1892 in his work on the Staunton Folio (No. 14) reached the conclusion that there was not sufficient evidence to correlate precisely the Virginia and West Virginia Devonian Formations with those of New York and hence proposed a new name for the Middle Devonian Group of rocks in the term Romney, named from the excellent exposures near that town in Hampshire County, West Virginia. This name has been adopted and is now in use by the United States Geological Survey and by the Maryland Geological Survey, but as the original New York formations are so readily recognizable in West Virginia, there would appear to be no reasons for discarding them while the law of priority gives entirely adequate and valid reason for their retention.

The fossils of this group are in very many outcrops characteristic of the New York sections. Near the base of the group are found characteristic fossils of the New York Onondaga, and above are fossils of Marcellus age with still higher strata carrying fossils of Hamilton age. The three divisions of the Middle Devonian have been traced continuously from the typical New York sections across Pennsylvania and Maryland into West Virginia, both by their characteristic fossils and by the lithological characters of the three groups. In Pennsylvania, the Geological Survey followed the New York classification to the Maryland Line, and the work of the Maryland Geological Survey shows this continuity to and into the State of West Virginia.

With this feature present of continuous correlation from New York into West Virginia, the adoption of a new name for the Middle Devonian does not seem to be required. There are difficulties in the field with poor and sometimes distantly removed exposures, and scarcity of fossils in some districts, which make the accurate mapping of these subdivisions very difficult and troublesome. The line can in such cases, however, be approximated, and it has been deemed advisable in the present Report to retain the New York nomenclature and to attempt at least to approximate their boundaries on the map.

Professor Prosser in his studies of the Maryland Devonian stratigraphy (Md. Geol. Survey, Middle Devon., p. 44) concludes:

"The evidence given above for correlating the Romney shales overlying the Onondaga Member, with the Marcellus and Hamilton stages of New York is considered conclusive, especially when it is taken into consideration that other sections in the Middle Devonian rocks of southern Pennsylvania, Maryland, and northern West Virginia present a similar array of facts in favor of such correlation."

He again in discussing this correlation, states (p. 46):

"This agreement in the correlation of the formations in western Maryland and southern Pennsylvania is important for the Second Survey virtually traced the Devonian and Silurian formations from New York across the state to Maryland. The writer has studied a part of the Pennsylvania region in the field and although in some of the classification in the northeastern part of the state he differed from the Pennsylvania Survey, in general the formations were accurately correlated with the standard ones of New York. Furthermore, in reference to the claim sometimes made that fossils are unreliable, it is to be said that in the Pennsylvania Survey greater dependence was placed upon the lithology, stratigraphy, and actual tracing of the formations in the field than upon fossils."

And in the discussion of the Hamilton fauna compared with that of New York, Prosser (p. 103) states that, "The above review of the paleontological evidence shows conclusively the extension of the New York Hamilton as far south in the Appalachian basin as Maryland and the northern part of West Virginia."

There seems to be no dispute in regard to the continuation of the New York divisions of the Middle Devonian southward into West Virginia, and in typical exposed sections there appears to be no trouble in the identification and separation of the three groups, and notwithstanding the difficulties in field map work of the groups, it seems more reasonable to retain the long-established names of the New York section than to adopt a new term.

THE HAMILTON FORMATION.

The Hamilton Formation was named from its exposures in Hamilton Township in New York not far from Utica. Lesley states that the surface of its outcrop extends from New York across eastern Pennsylvania southwest to the Susquehanna River five miles above Harrisburg, thence through Perry County and through Juniata, Huntingdon and Fulton Counties into Maryland and West Virginia, with a thickness in New York of 700 feet, thinning west to 300 feet. He states that it is the most fossiliferous formation in New York.

In Huntingdon County, Pennsylvania, Dr. I. C. White divided the Hamilton into five groups, as follows (Final Report, Penna. Geol. Survey, p. 1277):

Upper Shale beds, yellow, greenish, and gray, very fossiliferous, thickness 200 to 250 feet.
Upper Sandstone, bluish-gray to drab, some fossils.
Middle Shale beds, dull gray, weather to small chips, full of fossils about one to ten feet above base. Thickness 200 to 225 feet.
Lower Sandstone, dark gray to yellowish-brown in layers six inches to two feet thick, upper layers quite fossiliferous. Thickness about 50 feet.
Lower Shale beds, more or less sandy, few fossils, thickness 75 to 100 feet.

The total thickness of the Hamilton in this county is 550 to 665 feet, and in Bedford County, 793 feet.

In Maryland, Professor Prosser states (loc. cit., p. 50) that the Hamilton has a thickness of 1000 feet composed of shales and sandstones, the shales when fresh being blue or gray in color weathering to a greenish or yellowish-gray tint. The sandstones are blue or gray in color often less than one foot thick with two heavy ledges 30 to 75 feet, the lower one 850 to 1050 feet above the base of the formation, and the other at or near the top; also a conglomerate ledge is found 175 feet below the top in the area east of Hancock. The upper shales between the two large sandstones are very fossiliferous in many localities.

The Middle Devonian shales and limestones continue from Maryland across the Potomac into Morgan and Berkeley Counties of West Virginia, and show the three-fold division. The most extensive one of the three is the Hamilton which is highly fossiliferous in its upper portion. It rests below usually on the Marcellus Black Shales, and above is separated from the Portage by a heavy ledge of sandstone.

The upper shales are purplish-black, quite sandy, with glistening surfaces and break into slabby, or nodular masses especially near the top. Below they are smooth platy shales olive to greenish-black color and on weathering often become chocolate-brown to brownish-buff color. The shale also shows a tendency to weather to small blocks like a sand, called in the Pennsylvania Survey Reports "slate gravel".

There are a number of interbedded sandstones two to ten inches thick which in some ledges weather shaly and in others to angular blocks. Some of the shales also show a blocky character in seams two to six inches thick which look at a distance like sandstone ledges. The sandstones are usually greenish-gray in color and at the top is a massive ledge 50 to 60 feet thick which is near the top of the formation; and on the map the line between the Hamilton and Portage is drawn just above this sandstone. In some sections a heavy ledge of greenish-gray sandstone is found near the base of the Hamilton. This stratum is 45 feet thick on the Potomac east of Back Creek. Other ledges of sandstone come in the sections but they are usually of small thickness. One and a half miles west of Cherry Run Station a conglomerate was found on top of the ridge on both west county roads in the upper part of the Hamilton. The upper beds are very fossiliferous and contain forms typical of the Hamilton of New York.

OUTCROPS.—The most western outcrop of the Hamilton Formation in Morgan and Berkeley Counties is just west of Tonoloway Ridge and parallel to it extending northward to the Potomac just west of Great Cacapon Station, a belt about 1800 feet wide which shows the greenish-gray hard and compact sandstone at the top, 60 feet thick underlain by greenish-buff to olive shales broken by thin sandstone strata.

A belt of Hamilton rocks follows parallel to the Warm Spring Ridge on the east side through Berkeley Springs to the river at Hancock. It is one-half to three-fourths mile wide.

About two miles east of Third Hill Mountain is an area of Hamilton which extends east to Ferrel Ridge and north to the river. Another belt lies between this ridge and North Mountain, and the two unite north of Ferrel Ridge forming a broad belt four to five miles wide exposed along the river from Cherry Run Station to the limestones a mile and more east of Back Creek railroad bridge.

The following sections illustrate the character of the Hamilton strata near the eastern border of the Back Creek Valley outcrops. The first section was measured along the river bluffs as exposed in the cuts of the low-grade line of the Baltimore and Ohio Railroad. It probably does not quite reach the base of the formation. The base of the section was obscured by a fold, but the thickness of the section measured would indicate that the section is very nearly complete:

Section of Hamilton on Potomac North of North Mountain.

	Feet.
Sandstone, dark greenish-gray almost black, some nodular concretions in it	50
Slabby very sandy shales in large blocks almost like a shaly sandstone and at bottom full of fossils.	140
Fossil-bearing sandy shales	56
Sandy shales very few fossils	42
Blocky sandstone, gray, compact, hard	14
Shales weather spheroidal, many concretionary balls	60
Sandy buff to slate black color with fossils	6

	Feet.	
Sandy shales slabby with a few fossils	33	
Shales, some ledges shaly sandstone full of fossils, in more or less prismatic ledges by jointing	60	
Fine flaky shales	15	
Solid ledges of shales	76	
Shales in solid ledges and flaky shales	152	
Sandstone	8	
Shales with well-developed spheroidal weathering, and at bottom a ledge full of fossil brachiopods	126	
Concealed along railroad fill	118	
Shales with ten-inch ledge greenish sandstone, 8 inches chocolate-brown blocky shale and shales with two- to four-inch ledges blocky sandstone	50	
Shales with spheroidal weathering, thin ledges blocky sandstone, fossil casts in the shales	95	
Greenish-gray sandstone and shales	45	
Solid blocky greenish shale with four- to eight-inch blocky ledges through it, dip nearly vertical	50	1196

Another section was measured to west of Hedgesville on the county road from the contact of the Hamilton and Portage west across Back Creek and in this section while the basal part of the section is probably lacking, the section is regarded as being nearly complete. The details of this section are somewhat concealed, but it represents the general character of the Hamilton in this portion of the area. Further west the section could not be measured with any accuracy on account of the folding and the faulting near Ferrel Ridge.

Section of Hamilton West of Hedgesville, Berkeley County.

	Feet.	
Heavy ledge greenish-gray sandstone	36	
Sandy greenish-gray to buff shales with fossils	35	
Blocky sandy shales almost a sandstone	35	
Flaky shales weathering to a chocolate-brown color	85	
More solid shaly ledges	60	
Ledges very solid sandy shales	50	
Greenish to buff fine flaky shales	85	
Solid ledges of buff shales that weather to crumbly shales	120	
Shaly ledges greenish color weather chocolate-brown	102	
Purplish to black shales, pronounced spheroidal weathering	60	
Chocolate-buff shales	30	
Back Creek bottom and bridge, concealed	170	
Flaky chocolate-brown shales	224	
Dark-gray to black fine flaky shales weather brownish	40	1132

The Hamilton Shales were followed westward nearly to the east slope of Ferrel Ridge where it is apparently separated by the Marcellus from the Oriskany, and typical Hamilton fossils were found in the shales at this point, the most common being tribolite fragments of *Phacops rana.* The formation was then traced to good exposures at Soho and Holton, and typical fossils were found between these two places. To the west of Holton a heavy greenish-gray sandstone comes into the section apparently in the upper part though the folding in this area makes the horizon difficult to locate. Over much of this area especially at the good exposures near Back Creek, the spheroidal weathering is well shown in these shales.

The following section was measured by Professor Prosser across the river in Maryland from Great Cacapon Station. It shows the detailed structure of the Hamilton where the strata are well exposed in the comparatively recent cuts of the Western Maryland Railroad. With it is included his section at the same place of the lower formations which are described later in the present Chapter. The section is copied from the Pawpaw-Hancock Folio (p. 74):

Section of Middle Devonian Formations Opposite Great Cacapon (Prosser).

Hamilton Shales.	Feet.
Massive grayish to slightly greenish-gray sandstone, breaking into large irregular blocks; fossils rare; upper sandstone zone	59
Bluish-gray arenaceous shale, with a few intercalated thin sandstones. The shale breaks into irregular pieces and is very fossiliferous, containing *Spirifer mucronatus, Tropidoleptus carinatus, Chonetes mucronatus, Chonetes coronatus, C. setiger, Prothyris lanceolata, Paracyclas lirata,* etc	505
Bluish, not very thick bedded, sandstone and interbedded shale, constituting lower sandstone zone	57
Bluish shale and some thin-bedded sandstone	225
Thin, bluish, somewhat irregular arenaceous shale. The greater part of this zone is covered	479
Thickness of Hamilton	1325

	Feet.
Marcellus Shale Member.	
Thin-bedded bluish-black to black fissile shale containing *Leiorhynchus limitare*. The shale is greatly contorted and crushed, rendering it difficult to measure its thickness. About	170
Onondaga Shale Member.	
Concealed, approximately	100
Interbedded greenish-drab and black blocky shale in which Kindle found *Strophalosia truncata, Rhipidomella vanuxemi, Ambocoelia umbonata, Nucleospira concinna, Dalmanella lenticularis, Anoplea* cf. *nucleata, Leptaenisca* n. sp., *Styliola fissurella, Phacops cristata*, etc.	60
Thickness of Onondaga	169
Total thickness of Middle Devonian	1655 feet.

The following section was measured by Dr. Rowe and given in the Maryland Geological Survey Report on the Middle Devonian (p. 81). It was measured on the National Road just east of Hancock.

Section of Hamilton East of Hancock, Maryland (Rowe).

	Feet.	
Cross- and thin-bedded light olive sandstone with little or no shale. Top of Hamilton	55½	
Layer with numerous specimens of *Camarotoechia*	72	
Bluish-gray shales with a band of calcareous sandstone near the top. This zone is fossiliferous	260	367½

The Hamilton in certain zones of the formation is very fossiliferous and Swartz in the Pawpaw-Hancock Folio gives the following list of fossils as common in the Hamilton of this area (p. 80):

Athyris spiriferoides.
Camarotoechia sappho.
Chonetes mucronatus.
Chonetes coronatus.
Chonetes vicinus.
Cyrtina hamiltonensis.
Reticularia fimbriata.
Rhipidomella penelope.
Rhipidomella vanuxemi.
Spirifer granulosus.
Spirifer sculptilis.
Spirifer tullius.
Stropheodonta concava.
Stropheodonta demissa.
Tropidoleptus carinatus.
Cypricardella bellistriata.
Grammysia bisulcata.
Nucleospira concinna.
Palaeoneilo constricta.
Loxonema hamiltoniae.
Pleurotomaria capillaris.
Homalonotus dekayi.
Phacops rana.

THE MARCELLUS FORMATION.

The Marcellus group of black shales, with very few fossils, is stated by Lesley to be only 50 feet thick in western New York and seldom reaches a greater thickness than 300 feet though the maximum near the Susquehanna River was 800 feet. In New York it rests upon the Corniferous Limestone sometimes called the Upper Helderberg Limestone, which in turn rests on the Oriskany Sandstone. As the formation is followed westward in New York and through Pennsylvania, the limestone seems to be replaced by shales which were regarded by the Pennsylvania Survey as Marcellus, though now they are separated under the term Onondaga.

In western New York, Lesley states (Final Report, p. 1196) that the Marcellus is found in two divisions—the lower very black slaty and bituminous shales full of iron pyrites and concretions (septaria) and thin beds of limestone; and separated by this limestone from the upper division of more fissile, black shales and grading upward into the olive shales of the Hamilton. The fossils are small and fragile but well preserved in the New York exposures.

In central Pennsylvania, the Marcellus carries an iron ore seam about four feet thick with 35 per cent. iron in Huntingdon County, whose horizon is near the base of the Marcellus, making a good guide in the study of the stratigraphy in those sections.

In Maryland, Prosser (loc. cit., p. 49) states that the Marcellus is "composed principally of fissile black shale some of which weathers to a yellowish or buff color on long exposure". He finds that the lithological character agrees with the Marcellus of New York and that the fossils found are common in the same group in that State. Swartz in the same report (p. 98) reaches the conclusion that the character of the rocks and the fossils establish the Marcellus age of these rocks.

The Marcellus Formation in Maryland is shown to be about 170 feet in the section across the river from Great Cacapon quoted on a preceding page. It there consists of thin-bedded bluish-black fissile shale which is greatly contorted and crushed. South of Berkeley Springs, Kindle measured 250 feet of Marcellus Black Shales, though part of the thickness was estimated as it was covered by debris.

The following fossils are identified by Prosser from the Marcellus in the Maryland and West Virginia area (Pawpaw-Hancock Folio, p. 78):

Ambocoelia umbonata.
Camarotoechia prolifica.
Chonetes mucronatus.
Chonetes scitulus.
Chonetes lepidus.
Cyrtina hamiltonensis.
Leiorhynchus limitare.
Spirifer mucronatus.
Tropidoleptus carinatus.
Nucula corbuliformis.
Nuculites triqueter.
Styliola fissurella.
Phacops rana.

THE ONONDAGA FORMATION.

Kindle describes the Onondaga Shale member of the Middle Devonian as follows in the Maryland Devonian Report (p. 48):

"The Onondaga Shale is prevailingly lighter in color than the overlying Marcellus shale while many of the beds are blocky. Upon weathering it usually become buff or greenish-brown, and breaks into irregular fragments, resembling, in this respect, the upper part of the Hamilton member, and finally disintegrates into clay. Interbedded with the lighter strata, however, are beds of black, or dark brown, fissile shale, which resemble the shale of the overlying Marcellus very closely. Thin beds of dark, argillaceous limestone occur at several horizons and vary much in thickness and purity. They play a less important role in the Maryland sections than in Pennsylvania, the dark and drab shale almost, if not entirely, supplanting them locally. The thickness of this member varies from 100 to 150 feet."

This group has only recently been separated in the Pennsylvania and Maryland sections, and was supposed to be absent until the detailed work of Kindle. Clarke[1] has established a relation between the Onondaga and Marcellus somewhat similar to that between the Catskill and Chemung, in that the Onondaga and Marcellus do not represent successive periods of time throughout the formations, but that the lower beds of the Marcellus were deposited at the same time as the upper beds of the Onondaga. In New York, the Onondaga

[1]Bull. N. Y. State Museum, No. 49, pp. 115-138; quoted by Swartz, Md. Geol. Survey Report Middle Devonian, p. 89.

Limestones were forming at the west while Marcellus Shales or Clays were being deposited at the east. Swartz from his studies in Maryland concluded that "the shales replace successively lower and lower limestone beds as we approach the shore-line, until a large part of the deposits of Onondaga time may be represented by shale. Such appears to be the case in Maryland".

The section of the formations opposite Great Cacapon, quoted on a preceding page, shows the Onondaga at that place to be about 160 feet thick and made up of interbedded greenish-drab and black blocky shale with fossils.

The following section was measured by Kindle and given in the Maryland Report (p. 59). The section was made on the east slope of Warm Spring Ridge about one and a half miles south of Berkeley Springs:

Section of Onondaga South of Berkeley Springs (Kindle).

Marcellus Black Shale and concealed..........250 feet.		
Onondaga Member.	Feet.	
Covered	35	
Black blocky argillaceous shale, full of fossils......	20	
Drab shale, weathering cherry-red in places, fossils scarce, *Craniella hamiltoniae, Leptostrophia perplana, Ambocoelia umbonata*......................	18	
Cream or light putty-colored clay shale, with some buffish layers..................................	10	83
Oriskany Sandstone....................................		

Swartz in the Pawpaw-Hancock Folio (p. 76) gives the following list of fossils collected by E. M. Kindle in the Onondaga near Berkeley Springs and opposite Great Cacapon:

Craniella hamiltoniae.
Rhipidomella vanuxemi.
Dalmanella lenticularis.
Leptaenisca n. sp.
Pholidostrophia n. sp.
Leptostrophia perplana.
Anoplia nucleolata.
Strophalosia truncata.
Ambocoelia umbonata.
Nucula cf. *corbuliformis.*
Nucleospira concinna.
Styliola fissurella.
Phacops cristata.
Bollia ungula.
Bollia obesa.
Craterellina n. sp.
Polygnathus sp.

CHAPTER IX.

THE DEVONIAN PERIOD—THE ORISKANY AND HELDERBERG FORMATIONS.

The Lower Devonian in Maryland and West Virginia includes two groups of rocks:

Oriskany Sandstone Formation.
Helderberg Limestone Formation.

THE ORISKANY SANDSTONE FORMATION.

The Oriskany or Formation No. VII of the First Pennsylvania Survey, was named from its exposures at Oriskany Falls near Utica, New York, where it is described as a pure, light-yellow sandstone.

In Pennsylvania, Lesley states (Final Report, Vol. 2, p. 1036):

> "The outcrops of Oriskany extend in straight and curved lines and many zigzags through nineteen counties, a total distance of 1100 miles; the formation however appearing and disappearing, thickening and thinning; varying in character from sandy shale to massive flint rock; in some places crowded with shells, at others almost destitute of them; in some places calcareous, in others with scarcely a trace of lime; in some places highly ferruginous, even containing iron enough to furnish furnace ore."

The sandstone has been worked in that State for glass sand in Huntingdon County, and, southwest of Lewiston, according to Lesley, it contains 98.84 per cent. silica and 0.34 per cent. iron oxide. He gives the maximum thickness in that county as 200 feet and in Perry County not over 25 feet. Some of the formation is a sandy limestone along the Helderberg Mountains in New York, and in sections on the Delaware and

Upper Juniata Rivers in Pennsylvania. The formation was called the Monterey Sandstone in the early Folios of the United States Geological Survey, but the term Oriskany is now used by that Survey.

In the work of the Maryland Survey, the Oriskany was divided into two groups, the Upper Oriskany or Ridgely Sandstone, and the Lower Oriskany or Shriver Chert. The Lower or Shriver Chert, according to the Maryland Survey Report on Lower Devonian (p. 91):

"Consists of a dark siliceous shale containing large quantities of black impure chert in the form of nodules or layers of nodules. Upon weathering both shale and chert become buff or yellowish in color and break into sandy fragments, the chert in some cases becoming spongy. The rock has the property of cementing upon exposure and is much used as a surfacing material for roads for which purpose it is admirably adapted. Where it outcrops the surface of the ground becomes covered with a thick mantle of gravel-like fragments, the resulting soil being well adapted to the cultivation of orchards and berries. This member occupies extensive areas upon the slopes of the mountans upon which the Oriskany outcrops in Alleghany County. The thickness of the Shriver Chert member is variable. In the more westerly localities it is about 100 feet thick. It thins eastward and is absent in Washington County. The fauna of this member is meager."

This Lower Oriskany or Shriver Chert is apparently absent in Morgan and Berkeley Counties, though it is given in a section across the river in Maryland from Great Cacapon, quoted in a later paragraph.

The Upper Oriskany which is mainly a sandstone formation was named, in the work of the Maryland Survey, the Ridgely Sandstone from the town of Ridgely across the river in West Virginia from Cumberland. It is described in Maryland as a calcareous sandstone, bluish-gray in color, very tough in fresh exposures, but on weathering disintegrates and forms a sand with large boulders of sandstone. Its thickness is given as 250 feet at the west and 50 feet near North Mountain. It is usually very fossiliferous.

In Morgan and Berkeley Counties, West Virginia, the Oriskany Sandstone in fresh exposures is a hard, coarse-grained, or granular, white, brownish-gray, gray to bluish-gray sandstone. In most of the exposures it is more or less stained by iron and its outcrop usually forms a ridge. Near Berkeley Springs it is almost snow-white and quite free from iron and clay. It there weathers to a crumbly white sand which is extensively quarried for glass sand. The white sand quarries will be described in a later Chapter of this Report on Mineral Resources of the Area.

The weathered sandstone in many ledges is apparently solid but crumbles in the hand. The roads crossing Warm Spring Ridge are deep in sand, while cliffs of more resistant sandstone project along the crest of the ridge. The sandstone, as followed south from Berkeley Springs on this ridge, appears to contain more of the harder ledges than to the north, and the sand seems to be more iron-stained, but here and there through the ridge are pockets of white sand free from iron, observed south to the state line. Some of the harder ledges contain vitreous quartz and have a closer-grained texture. Beds of white pebble conglomerate occur through the formation and are seen in the sand quarries especially in the first quarry southwest of Hancock, and also at various places along the ridge. The sandstone is full of fossil casts of shells typical of the Oriskany of Pennsylvania and New York.

On Ferrel Ridge the sandstone is dark gray in color due to dark particles through the rock. The quartz grains have a bluish color and vitreous lustre, and the rock is finely granular. Further south on this ridge the rock is dark gray, granular, and has a decided vitreous appearance, containing the bluish quartz grains which are rounded and mostly small, though a few of the grains are one-eighth inch in size. The rock weathers to a light-gray color with reddish-brown iron spots through it.

Near Tomahawk the formation is a sandy or siliceous limestone, light-gray color, granular, and sparkles with crystal plates of calcite, and is full of fossils. On the east slope of the ridge to the north of Tomahawk, the formation is a mass of black and white flints with boulders of sandstone further west. This flint surface, with the blocks of flint of considerable size and very little trace of soil near the surface at least, is considered as especially valuable orchard ground and this area contains some very large and productive orchards.

West of Cherry Run in the Baltimore and Ohio Railroad cut is a large outcrop of Helderberg Limestone overlain by a calcareous sandstone correlated with the Oriskany. The rock is grayish-brown color on weathered surfaces full of vitreous quartz grains so that it is almost like a quartzite. A number of dark streaks through the rock with minute flakes or points suggest mica. The rock is sparingly fossiliferous.

On Tonoloway Ridge there is an excellent exposure of the Oriskany where a new road has been cut through the point of the outcrop about eight miles south of Great Cacapon Station. The rock is white, granular, and quite hard in fresh exposure and full of fossils. Further north the sandstone is more or less iron-stained and there are many ledges of hard granular rock. At a number of points along the ridge the snow-white sandstone is seen and apparently quite free from impurities.

OUTCROPS.—The most western outcrop in this area is on Tonoloway Ridge in Morgan County. The Oriskany there forms the crest of the ridge and the upper eastern slope. It extends from Great Cacapon south in a narrow belt, 400 to 500 feet wide, but eight miles south of the town, it expands near where the river has cut through the ridge into a belt over 2000 feet wide. It forms the rocky hill of Little Mountain near the south end of Morgan County. The western slope of the ridge is composed of Middle Devonian Shales, while the steep eastern slopes to the river expose the Helderberg Limestone and the lower formations of the Silurian. The sandstone is crushed and prepared for building and engine sand at a small plant on the Maryland side opposite Great Cacapon. Rugged cliffs of the sandstone tower in the air along the ridge to the west of the river and they dip at a high angle so that the ridge is practically inaccessible from this side. Where the river cuts through the ridge, the high white sandstone cliffs are well exposed on the north side of the river with a low angle of dip, and here typical Oriskany fossils are abundant.

A belt of Oriskany Sandstone marks the top of Warm Spring Ridge and extends a short distance down its eastern slope. It is marked by low cliffs of persistent rock fairly resistant to weathering, but most of the ledges on long exposure become crumbly and form a loose sand. To the north the top of the ridge has a rounded outline and but few cliffs are found. The formation is well exposed by the various crossroads. A good exposure is also found at Rock Gap, eight miles south of Berkeley Springs where it forms an apparently solid wall sloping at a high angle to the east valley, but when struck with the hammer it is found to be soft and crumbly, it being almost impossible to secure a solid hand specimen of the rock. The width of this outcrop is 800 to 900 feet. From Berkeley Springs north the sandstone is very white and free from iron. In it occur a number of large pockets of loose white sand, and in this area is a large and prosperous glass sand industry.

The outcrop narrows northward and decreases in thickness. It reaches the Potomac one mile northwest of Hancock Station were it is only a few feet thick. The conglomerate in this area is composed of small or large white pebbles imbedded in a loose white sand matrix which crumbles to a gravel. In the southern part of Morgan County, the Oriskany is 225 feet thick, and over 400 feet near Berkeley Springs.

A small outcrop of Oriskany is exposed in the railroad cut west of Cherry Run Station. It has a shallow thickness on the Helderberg anticlinal fold here and extends only a short distance south.

Ferrel Ridge west of North Mountain in Berkeley County is flanked on the west side by a narrow belt of Oriskany which here is a dark- to light-gray sandstone hard and resistant to weathering. It enlarges to the north end of the ridge covering the lower slope to the run level and well up on the ridge. It follows the east side of the ridge in a broad belt with a faulted narrow zone extending southward past Tomahawk. The sandstone on the east slope contains a considerable quantity of chert or flint blocks which cover the ground on the terrace ridge north of Tomahawk. Near this town the

PLATE XV.—Anticline in Hamilton Shales (West End) with Heavy Sandstone Stratum at Base, in deep cut of Baltimore and Ohio Railroad North of North Mountain Station.

upper portion of the Oriskany is a gray hard siliceous limestone, very fossiliferous, while the lower part is a sandstone.

A very narrow belt of Oriskany follows the west slope of North Mountain nearly to the Potomac River. It is iron-stained and is a blocky resistant sandstone but its outcrop is somewhat concealed by debris and it is difficult to measure its width or thickness.

The character of the Oriskany Formation in the western outcrop is shown in the following section made by Stose and Ulrich in Maryland opposite Great Cacapon Station and given in the Maryland Survey Report on the Lower Devonian (p. 187):

Section of Oriskany Opposite Great Cacapon (Stose and Ulrich).

	Feet.
Onondaga black and drab shale.	
Oriskany Formation, Ridgely Member.	
Soft, porous, brown fossiliferous sandstone, some beds a fine dark vitreous quartz conglomerate. Very fossiliferous layer at base	40
Massive beds, 10-20 feet thick, of white fossiliferous quartzose sandstone	85
Softer, thinner-bedded, fossiliferous sandstone weathering yellowish	90
Hard, quartzose sandstone	2
Soft, thin-bedded, yellowish sandstone. Few fossils	45
Covered. Soft sandstone debris	140
	402
Shriver Chert Member.	
Yellow, probably calcareous, fossiliferous shale with much chert, containing Oriskany fossils	15
Total thickness of Oriskany	417
Helderberg Formation.	

This section is interesting in showing the presence of the Lower Oriskany or Shriver Chert Member, and it is regarded by the authors as the most eastern outcrop of this member, which is not found in the Morgan or Berkeley Counties sections.

Stose gives the following section of the Oriskany near Tomahawk, West Virginia (Pawpaw-Hancock Folio, p. 69).

Section of Oriskany at Tomahawk (Stose).

Romney Shale.		
Oriskany Formation.	Feet.	
Massive calcareous white sandstone containing numerous specimens *Spirifer arenosus*. Hard blue siliceous limestone with black flint below, very fossiliferous..................................	45	
Chiefly fossiliferous limestone and black flint......	16	
Hard granular sandstone with white quartz conglomerate at top..................................	3	
Concealed. Thick beds of limestone in part.......	41	
Chiefly hard siliceous fossiliferous limestone, weathering to sandstone and chert..................	75	
Siliceous gray limestone with interbedded black flint, and thin fossiliferous limestone...........	33	213
Concealed. Probably Helderberg.		

Stose gives the following list of typical Oriskany fossils collected in the area of the Pawpaw-Hancock Folio (p. 72) as identified by Ulrich:

Orbiculoidea sp. undet.
Rhipidomella musculosa.
Hipparionyx proximus ?
Stropheodonta lincklaeni.
Stropheodonta magnifica.
Chonetes cf. *cumplanata.*
Spirifer arenosus.
Spirifer cumberlandiae.
Spirifer hartleyi.
Spirifer murchisoni (*arrectus*).
Spirifer tribulis.
Anoplia nucleata.
Leptocoelia flabellites.
Meristella lata.
Camarotoechia barrandei.
Rensselaeria ovoides.
Megalanteris ovalis?
Megambonia bellistriata.
Avicula textilis var. *arenaria.*
Platyceras gebhardti.
Platyostoma ventricosum.
Tentaculites cf. *elongatus.*
Bryozoa (several unpublished species).

THE HELDERBERG FORMATION.

The Helderberg Formation has usually been included with the Silurian Group and it is so given in most text-books on Geology. The work of John M. Clarke and Schuchert appears to have proved that the Helderberg fauna as preserved in fossil state is more closely connected with the Devonian than with the Silurian, so that this formation is now made the base of the Devonian.

Schuchert from a comparative study of the fossils of the Helderberg from New York across Pennsylvania into Maryland and West Virginia reached the following conclusion:[1]

[1]Bull. Geol. Soc. Amer., Vol. II, p. 277; 1900.

"From the foregoing summary of the Helderbergian fauna it is evident that most of the characteristic Siluric genera of trilobites, brachiopods, and crinoids are there absent. This might be expected, for, as has been seen in the previous Chapter, about two per cent. of the Helderbergian fauna are derived from the Siluric. On the other hand, in some of the trilobites, Bryozoa, and pelecypods, many of the gastropods, but more particularly in the diversified brachiopods, are met organic groups, which in their culmination are characteristic of the Devonic. It can not be denied that the Helderbergian fauna has a Siluric facies, yet these types either have greater differentiation in species or the form attains a larger size. The fact that nine per cent. of the Helderbergian fauna pass into a generally accepted Devonic horizon, the Oriskany, outweighs the evidence of a Siluric facies and specific derivatives. The writer therefore concludes that the Helderbergian has a fauna unlike the Siluric, but one in harmony with the Devonic and its position near the base of that system."

At the present time there seems to be little doubt that the proper place for the Helderberg Formation is in the Devonian period. The detailed work of Mr. Schuchert on the fauna of this formation, which is discussed very fully in the paper above quoted and which leads him to the conclusion above given, seems to clearly establish this correlation and it has been generally accepted.

In some of the early folios of the United States Geological Survey, the limestone formations below the Oriskany Sandstone, including the Helderberg and Silurian Limestones, were named the Lewiston, but the term has since been abandoned. The Helderberg in New York has a thickness of about 400 feet, and it extends southwest across Pennsylvania where it was early known as Formation VI, across Maryland and West Virginia into Tennessee. Its best stratigraphic development, according to Schuchert, is in western Maryland in the Cumberland area.

In Huntingdon County, Pennsylvania, Dr. I. C. White found the thickness of the Helderberg Formation to be 300 to 400 feet and he recognized the following groups (Final Report, Vol. 2, p. 991):

"An Upper Division—consisting of impure and shaly limestone and containing a 25-foot massive layer with *Stromatopora* fossils ....133 feet

"A Middle Division—dark blue massive limestone, not fossiliferous and containing mostly good limestone beds...............90 feet

"A Lower Division—of shaly impure limestone........170 feet."

The **Becraft** division was in the early New York geology called the **Upper Pentamerus Limestone** and also the **Encrinal Limestone,** while the **Coeymans** was the **Lower Pentamerus,** and received its present name from Becraft Mountain in Columbia County, New York, where it was named by Darton.

In Maryland it is described as a gray sandy limestone, containing much black chert, and there is found only in Washington County where it is about 85 feet in thickness. Its typical fossil is *Rensselaeria subglobosa.* "The upper limit of the New Scotland is shown by the transition from the New Scotland white chert with a little interbedded limestone, to the Becraft Limestone carrying a smaller amount of black chert."

The Helderberg Limestone outcrops in several belts in Morgan and Berkeley Counties, West Virginia. It is usually a light to dark bluish-gray granular limestone, often showing streaks and plates of calcite which in some cases become so numerous that the rock is a sparkling crystalline mass. It is usually very fossiliferous. In some exposures it is a hard compact dark-gray almost black rock with few fossils.

On the ridge back of Berkeley Springs, it is a dark-gray very coarse-grained limestone breaking along smooth planes and with very few fossils. Further north on this ridge it changes to a gray hard limestone which breaks irregularly and carries some fossils, its upper portion containing a considerable quantity of white flint.

On Ferrel Ridge, the limestone is dark- or bluish-gray, carrying black flint and full of fossils. Its lower ledges here carry fossil corals and crinoid joints but few other fossils and the rock is dark in color. Near Tomahawk some of the ledges are quite siliceous and others show a cobbly outcrop which is characteristic of many of the other outcrops. The limestone usually occurs in massive ledges broken by well-defined joint-planes. It is quarried for road purposes on a small scale back of Berkeley Springs and near Tomahawk as well as at a number of small roadside quarries. It is burned for lime north of Jones Spring.

OUTCROPS.—The Helderberg Limestone is found in a long narrow belt just west of the Oriskany outcrop on the east slope of Tonoloway Ridge in Morgan County extending north to the river at Great Cacapon and is less than 300 feet wide. This outcrop from the character of the rock in its massive form and its cobbly weathering and resting on the Tonoloway Limestone suggests its correlation with the Keyser Member of the Helderberg. Its thickness in Maryland across the river from Great Cacapon is given by Swartz in the Maryland Survey Report as 293 feet.

A belt of Helderberg Limestone follows the west upper slope of Warm Spring Ridge between the Oriskany at the top of the ridge and the Tonoloway below. This belt is about 500 feet wide and is probably mostly in the Keyser division. It reaches the Potomac about a mile southwest of Hancock Station where it is exposed in the railroad cut for some distance.

A small outcrop is seen about three-fourths mile northwest of Cherry Run Station and extends about a half mile south across the county road. It is a hard bluish-gray granular limestone with fossils and it is described by Schuchert in the Maryland Report (p. 179) as including the Becraft and New Scotland divisions of the Helderberg.

An outcrop of Helderberg Limestone follows around Ferrel Ridge, forming a long narrow belt on the west side and a broader faulted belt on the east side, passing south about a quarter mile west of Tomahawk. It apparently includes Becraft and New Scotland fauna. The formation is not found along North Mountain although the Oriskany outcrops along the west slope. A small mass of Helderberg is found at the east end of the Baltimore and Ohio Railroad cut north of North Mountain Station. It lies between the Martinsburg and Devonian Shale contact on the west side of the cut. It is full of fossils and is probably the Becraft Member.

The following section of the Helderberg was measured by the Maryland geologists opposite Great Cacapon. Swartz states that this is the best section of the Lower Devonian exposed east of Cumberland (p. 162):

Section of Helderberg Opposite Great Cacapon (Md. Geol. Survey).

Helderberg Formation.	
New Scotland Member.	Feet.
Residual clay after limestone filled with white blocky chert with numerous fossils	12
Coeymans Member.	
Hard, blue-gray, mottled and fine black-speckled limestone, full of fossil fragments	8.5
Keyser Member.	
Somewhat lamellar limestone with argillaceous and purer, fossiliferous, subcrystalline bands *Lioclema subramosum* and *Strophonella* sp	66
Coarsely cobbly to irregular lamellar impure limestone with purer fossiliferous bands	26
Very shaly platy limestone full of *Tentaculites gyracanthus, Meristella, bryozoa,* etc	3
Shaly cobbly limestone solid when fresh, fossils	7
Very shaly cobbly limestone with fossils	2.5
Dark gray-blue limestone coarsely cobbly with fossils	10
Cobbly limestone with surface full of *Tentaculites gyracanthus* and other fossils	2
Cobbly limestone containing reefs of *Stromatoporoids* also other fossils	2
Coarse cobbly argillaceous limestone with fossils	3
Cobbly limestone. *Leptaena* abundant throughout, also other fossils	14
Rather shaly cobbly limestone, with variety of fossils	12
Massive cobbly limestone with fossils	4
Somewhat shaly limestone breaking into irregular laminae with fossils	6
Single layer of finely cobbly limestone, basal part bored by worm-tubes. Fossils	24
Somewhat clayey finely cobbly limestone	2.8
Slabby crinoidal limestone containing some corals.	1
Finely cobbly limestone, massive when fresh, but breaking up on weathering into irregular pieces and cobble. Small reef of *Stromatoporoids* and *Favosites* near top and a thicker one near base	21
Subcrystalline limestone, banded with thin clay seams. Contains fossil fragments	5
Subcrystalline limestone, irregularly bedded with thin clay seams and containing large crinoid columns. Other fossils	5
Thick-bedded, subcrystalline limestone with fossils	7
Finely cobbly limestone with *Favosites* and massive *bryozoa* and other fossils	6.5
Thin slabby and shaly limestone, argillite in part, fossils	4
Massive dark-blue limestone with *Favosites* near base	13.6
Massive dark-blue nodular limestone	19
Thin-bedded dark-blue limestone with fossils	21.2

	Feet.
Thin-bedded dark-blue limestone weathering nodular, *Rhynchospira globosa* var. abundant.........	8.8
Thin-bedded dark-blue limestone weathering nodular. At base occurs *Chonetes jerseyensis*.......	6.6
Thin-bedded nodular blue limestone carrying crinoid fragments and other fossils..................	19.6
Concealed, with occasional outcrops of thin-bedded nodular limestone...........................	10
Total thickness...........................	293.1
Thickness of Keyser Member.............	272.6

A section which shows good exposures of the upper members of the Helderberg was measured at the outcrop three-fourths mile northwest of Cherry Run in Morgan County. This section was measured by Professor Schuchert and is quoted from the Maryland Survey Report on the Lower Devonian (p. 179):

Section of Helderberg West of Cherry Run, Morgan County (Schuchert).

	Feet.
Oriskany Formation, light-gray limestone...10 Feet.	
Helderberg Formation.	
Becraft Member.	
Dark-blue arenaceous limestone with lumps of black chert. The fauna is most abundant in the upper half. *Rensselaeria subglobosa, Anoplotheca flabellites, Spirifer cyclopterus, S. concinnus, Cyrtina rostrata, Eatonia medialis, E. peculiaris, Uncinulus vellicatus, Rhipidomella assimilis*	85
New Scotland Member.	
Gray heavy-bedded limestone with chert, mostly covered	50
Light-gray cherty limestone, *Spirifer macropleurus, S. cyclopterus, S. perlamellosus, Trematospira equistriata, Anoplotheca concava, A. flabellites, Rhipidomella oblata, Dalmanella perelegans, D. eminens, Streptelasma?, Atrypina imbricata,, Eatonia singularis?, Leptaena rhomboidalis, Uncinulus vellicatus, Camarotoechia altiplicata*....	15
Thickness of New Scotland Member....	65
Total thickness........................	160

Stose in the Pawpaw-Hancock Folio (p. 57) gives the following section of the Helderberg near Tomahawk in Berkeley County:

Section of Helderberg Near Tomahawk, Berkeley County (Stose).

	Feet.	
Oriskany Formation.		
Helderberg Formation.		
Largely concealed. Some dark fine-grained limestone exposed. Contains Becraft fauna	90	
Calcareous sandstone with shales below	13	
Thick-bedded massive limestone with large *Spirifer macropleura* and numerous shells of New Scotland fauna	79	
Banded light-gray calcareous sandstone	10	
Thick-bedded coarse limestone with wavy parting, weathering cobbly and containing *Bryozoa* and shells of Coeymans type	22	
Largely concealed. Shale at base, dense limestone above, and loose fragments of a 2-foot bed of coarse sandstone 20 feet below the top	84	
Chiefly cobbly limestone with some thin-bedded and shaly limestones	32	
Shale with 6-inch bed of black chert	6	
Massive coarse granular limestone with *Favosites*	2	
Massive cobbly limestone with numerous *Favosites* in lower part	25	
Dark siliceous limestone	1	
Crystalline, rough-bedded limestone, coarse-grained above, with *Favosites* and crinoid stems	16	380
Tonoloway laminated drab limestone.		

The thickness of the Helderberg in this area according to the above sections is 160 to 380 feet.

In connection with the Stose Folio Report on the Pawpaw-Hancock Area, Mr. Ulrich made a very detailed study of the fossil fauna of the Helderberg of that locality and the following results of this study are given by Stose in the above Report:

"In the Potomac Valley, between North Mountain on the east and Keyser, W. Va., on the west, the Helderberg Formation presents four broadly conceived faunal zones. The three upper zones—those containing the Coeymans, New Scotland, and Becraft faunas—are well known as formations of the Helderberg group in New York and New Jersey. The lowest faunal zone is the most persistent and also the most important zone of the formation as developed in areas near the Potomac in West Virginia, Maryland, and southern Pennsylvania. This zone is excellently exposed both in fresh quarry cuts and in weathered outcrops at Keyser, W. Va. It is partly represented in New York by certain beds which have hitherto been erroneously identified with the 'Tentaculite' or Manlius limestone, but no appropriate name has been applied to it.

"At no single locality are all these four zones fully developed and at most places one or another is entirely absent. The lower third or so of the lowest zone at Keyser seems altogether wanting east of Hancock, while the Becraft fauna is unknown west of that town. The Coeymans fauna, though generally recognizable, is irregular in its occurrence and possibly locally absent. It may be absent, for instance, in the Great Cacapon section, though it is probably represented in the 8½-foot bed near the top (bed 26 in the section). The New Scotland fauna is perhaps everywhere present, but the zone containing it varies greatly in thickness. At Great Cacapon, where the zone forms the top of the formation, it is but 12 feet thick; at Tomahawk and near Warren Point, in the eastern part of the area, the zone is 60 to 90 feet thick; between Cumberland and Keyser its thickness varies between 25 and 65 feet. As has been stated the lower zone at Keyser also varies from place to place, but so far as known in Maryland, its thickness seems never to fall under 100 feet. At Tomahawk about 150 feet of beds are referred to it, at Great Cacapon 262 feet, at the Devils Backbone, near Cumberland, about 280 feet, and in the Keyser quarries about 290 feet. Finally, it should be stated that no beds were observed in Maryland corresponding to the Port Ewen limestone, the uppermost formation of the Helderberg group in New York.

"Although each of the three upper zones is practically indivisible on faunal grounds, the relatively thick zone at the base of the formation may be divided into at least three subzones. These are easily distinguished by fossils confined to the several subdivisions or by diagnostic associations of species. The lowest of these subzones is commonly absent, but is well developed in the vicinity of Hancock and Great Cacapon, where it comprises beds 1 to 4, aggregating about 92 feet of limestone. To the west it is well exposed at the base of the Helderberg in the railroad cut at Potomac, Md., and in the quarry at Keyser, W. Va. A fauna including *Cyphotrypa rotundata. Schuchertella deckerensis, Chonetes jerseyensis, Spirifer eriensis, Rhynchonella litchfieldensis*, and *Leperditia gigantea*, or any four of these species, may be confidently accepted as indicating this subzone.

"The second of these subzones, though generally present, varies greatly in thickness. At Potomac only its uppermost part was recognized, but at other localities between Hancock and Keyser lower beds are intercalated which bring the total thickness of the subzone from 50 feet up to nearly 100 feet. The top consists of a very persistent and usually massive bed that is recognized at once, especially in the sections west of the Hancock quadrangle, by the abundant valves of a small variety of *Gypidula galeata* that it contains. The lower beds also contain widely recognizable fossil horizons. One of these lies from 30 to 50 feet beneath the *Gypidula* bed and is notable for its abundant remains of numerous cystids and crinoids that have been seen only in this part of the section. Though highly fossiliferous chiefly to the west of Cumberland, the cystid bed has been noted to the east also as far as Hancock. *Camarocrinus stellatus* is confined to a layer between the cystid and *Gypidula* beds. In the vicinity of Great Cacapon a small *Stromatopora* and *Favosites* reef holds a simlar position and helps in locating the more important adjacent fossil horizons.

"Although more subzones were indicated in the field, it seems inadvisable in the present state of our knowledge to attempt a further subdivision of the remainder of the zone. However, there are at least three and probably four fossil horizons above the *Gypidula* bed that may be said to be generally recognizable. The lowest of these lies directly above the *Gypidula* bed and is usually a shaly limestone containing many *Bryozoa* of which a species of *Petalotrypa* is the best for purposes of identifying the bed. Large specimens of *Chonetes jerseyensis* though unknown in the underlying subzone, are not infrequently found in this bed. The corresponding horizon in the Great Cacapon section was not positively recognized, but it is thought to belong between the base of bed 13 and the top of bed 16.

"The *Petalotrypa* bed is everywhere succeeded by a more or less well-developed *Stromatopora* reef which usually forms a single massive ledge. Over this reef is a third widely distinguishable horizon, in places shaly, that commonly contains such diagnostic fossils as *Beachia* n. sp., *Rensselaeria mutabilis* var., and a new variety of *Spirifer vanuxemi*. A late mutation of *Tenaculites gyracanthus* occurs very plentifully and as it seems to be confined to this bed and the genus is rare or absent in the other subzones, it is of considerable value in correlating the beds of the Helderburg limestone in Maryland. Locally this *Tentaculites* bed includes or is followed by another *Stromatopora* bed.

"Finally, a still higher bed, containing few fossils except a late form of *Leperditia alta*, appears in the vicinity of Cumberland and at Keyser. This bed has not been recognized in the Great Cacapon section, in which, moreover, the upper part of the zone—the beds above the main *Stromatopora* reef—is thinner than in the more western sections mentioned. In view of these facts it seems probable that shallowing and partial withdrawal of the sea took place before the more extensive withdrawals and temporary land conditions indicated by physical criteria at the end of the lower faunal zone and again at the end of the zone containing the Coeymans fauna.

"Comparisons with formations in New York and New Jersey are appended to each of the following lists of partially identified fossils collected from the faunal zones of the Helderberg limestone in Maryland. The species thought to be diagnostic of the respective zones are distinguished by an asterisk.

"Lowest fauna in the Helderberg limestone, procured chiefly from beds 1 to 4 of the section opposite Great Cacapon.

Diphyphyllum integumentum.
**Cyphotrypa* n. sp.
Trematopora sp. undet.
Pholidops ovata?
Stropheodonta bipartita.
**Schuchertella deckerensis.*
**Chonetes jerseyensis.*
Spirifer vanuxemi.
Spirifer eriensis.
Whitfieldella nucleolata.
Rhynchospira globosa.
Rhynchonella formosa.
Rhynchonella litchfieldensis.
Rhynchonella? lamellata.
Uncinulus mutabilis.
Tentaculites gyracanthus.
Leperditia altoides.
**Leperditia gigantea.*
**Beyrichia* n. sp.
Kloedenia barretti.
Kloedenia sussexensis.
Kloedenella clarkei.

"This fauna is regarded as indicating the time of the lower and middle beds of the Decker limestone in the Delaware Valley in northwestern New Jersey and northeastern Pennsylvania. Locally, as at Potomac, Md., a higher coral zone is developed that is thought to correspond to the upper coral-bearing beds of the Decker limestone as described by Weller in New Jersey. This upper subdivision is marked by *Cladopora rectilineata*, the slender branching coralla of which occur in great abundance at Potomac. It is of sufficient interest to repeat here that the coral zone at this locality is followed almost immediately by the *Gypidula* bed.

"Second fauna of the Helderberg limestone, represented in beds 5 to 25 of the section opposite Great Cacapon.

- *Stromatopora* sp. undet.
- *Favosites helderbergiae.*
- *Favosites helderbergiae praecedens.*
- **Striatopora* sp. undet.
- *Cladopora rectilineata.*
- **Cladopara multiseriata.*
- **Aulopora schohariae.*
- **Aulopora n. sp.* (Very slender).
- **Vermipora* cf. *serpuloides.*
- *Diphyphyllum integumentum.*
- **Prismatophyllum* sp. undet.
- *17 cystids of the genera *Pseudocrinites, Sphaerocystites, Jaekelocystis, Tetracystis, Lepocrinus.*
- *5 or 6 genera of crinoids.
- *Numerous *Bryozoa,* most of them undescribed and characteristic of this zone, representing the following genera: *Ceramopora, Fistuliporella, Eridotrypa, Cyphotrypa, Lioclema, Stromatotrypr, Petalotrypa, Fenestella, Semicoscinium, Orthopora.*
- *Pholidops ovata.*
- *Dalmanella concinna.*
- *Rhipidomella oblata* var. *emarginata.*
- *Uncinulus pyramidatus.*
- *Uncinulus nucleolatus.*
- **Gypidula galeata* var.
- **Mytilarca* sp. undet.
- **Amphicoelia?* n. sp.
- **Grammysia* n. sp.
- *Conularia pyramidalis.*
- *Tentaculites gyracanthus* var.
- **Dalmanella* cf. *postelegantula.*
- **Orthostrophia cf. strophomenoides.*
- *Strophonella geniculata.*
- *Schuchertella deformis.*
- **Schuchertella* cf. *woolworthana.*
- **Chonetes jerseyensis.*
- *Leptaena rhomboidalis.*
- **Spirifer vanuxemi* var.
- *Spirifer octocostatus.*
- *Spirifer modestus.*
- **Merista* typa.
- *Meristella laevis.*
- **Meristella* cf. *arcuata.*
- **Nucleospira* cf. *elegans.*
- *Rhynchospira globosa.*
- *Atrypa reticularis* var.
- **Rensselaeria mutabilis* var.
- **Beachia* n. sp.
- *Rhynchonella formosa.*
- *Rhynchonella litchfieldensis?*
- *Rhynchonella transversa?*
- *Rhynchonella lamellata.*
- *Leperditia altoides.*
- *Klodenia kummeli.*
- **Beyrichia* n. sp.
- *Kloedenella clarkei.*
- *Kloedenella pennsylvanica.*
- *Kloedenella turgida.*
- *Kloedenella hieroglyphica?*
- **Octonaria* n. sp.
- *Calymene camerata.*

"More than 100 species from this subzone are contained in the collections of the National Museum; and over two-thirds of these are strictly diagnostic. Taken as a whole the fauna is decidedly Helderbergian, most of the brachiopods, for instance, passing into the zones of the typical Coeymans and New Scotland faunas with so little change in character that it is difficult and often impracticable to distinguish them. On the other hand, most of the corals and ostracods, the trilobite, and a few of the brachiopods are more closely related to the preceding fauna and the Tonoloway fauna. This relation, together with the fact that the larger part of the fauna is confined to the lowest of the four Helderbergian zones recognized in Maryland, strongly suggests an older stage of the Helderberg group than is known or recognized in New York; and the truth of this suggestion is established by the occurrence of a typical Coeymans fauna above this lowest zone in Maryland. That this fauna is not the equivalent of the Cobleskill and Manlius faunas of New York, as has been supposed heretofore, is proved not only by its strong Helderbergian aspect but more positively by the presence in the lower Tonoloway, some 300 to 600 feet beneath the Helderberg in Maryland, of a fauna that agrees more closely with the typical Cobleskill and Manlius faunas.

"Coeymans fauna from the Pawpaw-Hancock and adjacent areas.

Orthopora regularis.
Rhipidomella oblata.
Leptaena rhomboidalis (large var.).
Strophonella punctulifera.
Schuchertella woolworthana.
**Gypidula* (*Sieberalla*) *galeata* (typical form).
Spirifer cyclopterus.
Meristella laevis.
Anoplotheca concava.
Atrypa reticularis.
Uncinulus nucleolata.
Uncinulus mutabilis.

"Neither the Coeymans fauna nor the beds of this zone are as well developed in this region as in the Helderberg Mountains of New York. *Gypidula galeata,* which may almost always be found after a few minutes search, is the principal guide fossil. Although a smaller variety of the species is widely distributed in the underlying zone, the typical form of the species and the zone of which it is diagnostic can be at once distinguished by its associated fossils. A number of species, like *Spirifer cyclopterus, Strophonella punctulifera,* and *Schuchertella woolworthana,* are unknown beneath beds containing the Coeymans fauna; hence, the presence of any of these with *Gypidula galeata,* may, according to present information, be regarded as positive evidence of the typical Coeymans fauna.

"New Scotland fauna from the Pawpaw-Hancock and adjacent areas.

Corals.
**Edriocrinus pocilliformis.*
**Monotrypa* (*Ptychonema*) *tabulatum.*
**Dalmanella eminens.*
**Dalmanella perelegans.*
Dalmanella planiconvexa.
Rhipidomella oblata.
Leptaena rhomboidalis.
**Stropheodonta becki.*
**Strophonella headleyana.*
Strophonella punctulifera.
**Strophonella cavumbona.*
Schuchertella woolworthana.
Spirifer cyclopterus.
**Spirifer macropleura.*
Spirifer perlamellosus.
Spirifer concinnus (?)
Meristella subquadrata.
Meristella arcuata.
**Trematospira deweyi.*
**Trematospira equistriata.*
**Trematospira multistriata*
Nucleospira elegans.
Nucleospira ventricosa.
Atrypa reticulata.
**Atrypina imbricata.*
Anoplotheca concava.
Anoplotheca flabellites.
**Camarotoechia altiplicata.*
Uncinulus mutabilis.
Uncinulus vellicatus.
Eatonia medialis.
Eatonia peculiaris.
Eatonia singularis.
Rensselaeria mutabilis.
**Platyceras spirale.*
Platyceros. gebhardti.
Platyceras bisinuatum.
**Phacops logani.*

"In Maryland, as in New York, the zone of the New Scotland fauna is the most fossiliferous zone of the Helderberg. Though there are many other forms, and most of them characteristic of the zone, it is only the brachiopods that are very common. Fortunately, there are enough of the latter that are either strictly confined to the New Scotland fauna or occur only rarely outside of it to render the identification of the zone exceptionally easy. Almost any of the species marked with an asterisk (*) may be relied on, and it is a poor outcrop indeed that does not quickly yield several of these. The cherty beds are especially prolific.

"**Becraft fauna from the Pawpaw-Hancock and adjacent areas.**

Crania sp. undet.
Dalmanella planiconvexa.
**Rhipidomella assimilis.*
Schuchertella woolworthana.
**Spirifer concinnus.*
Spirifer cyclopterus.
**Cyrtina rostrata.*
Meristella lata (?).
Meristella arcuata.
Nucleospira elegans.
Atrypa reticularis.
Anoplotheca flabellites.
Anoplotheca concava.
**Gypidula pseudogaleata.*
Rhynchonella eminens.
Rhynchotreta (?) n. sp.
Plethorhyncha campbellana.
Eatonia medialis.
Eatonia peculiaris.
**Rensselaeria aequiradiata.*
Rensselaeria aequiradiata var.
**Rensselaeria subglobosa.*
**Phancrotrema labrosa.*"

CHAPTER X.

THE SILURIAN SYSTEM.

Below the Devonian is the group of rocks included in the **Silurian System**, a name given by the English geologists in the early days of stratigraphical work in England. It was formerly designated as the Upper Silurian in distinction from the Lower Silurian, but the lower group has now been given another name, and the prefix Upper is dropped from the nomenclature.

The **Silurian System** of rocks is marked at the base by a heavy sandstone deposit, the Medina, which in central Pennsylvania reaches a thickness of nearly 2000 feet. Above this sandstone is a series of shales and sandstones, with solid and shaly beds of limestone that was named in the early days of New York geological work the **Clinton**, which has a broad extent westward into Ohio and Wisconsin and southward into Alabama. It contains beds of red hematite iron ore in Pennsylvania, Wisconsin, West Virginia, and in Alabama. Above this group are the **Niagara Limestone** and **Shale**, which also have a wide extent westward into Ohio, Illinois, Wisconsin, Iowa, and in the Black Hills of South Dakota, but southward from New York it is doubtfully present in Pennsylvania and is supposed by Stose and Swartz to be absent in Maryland and West Virginia, unless it be represented by their McKenzie Formation*, but the W. Va. Geological Survey regards the McKenzie as Niagara. At the top is the **Salina Group** of limestones and shales usually non-fossiliferous or only sparingly fossiliferous. In New York State they carry valuable deposits of salt and gypsum, also natural cement limestones. The

*Pawpaw-Hancock Folio, pp. 5, 6, and 24.

PLATE XVI.—Symmetrical Anticline of Bloomsburg Red Sandstone at Roundtop, Md. (Photo from Pawpaw-Hancock Folio of U. S. Geological Survey).

cement rock continues southward and was once worked at Roundtop and Cumberland, Maryland, but the salt and gypsum are absent showing a very different condition of the seas southward, more open water and an absence of shore lagoons.

The subdivisions of the Silurian are as follows:

Salina Formation.
Niagara Formation (McKenzie of Stose and Swartz).
Clinton Formation.
Medina Formation.

THE SALINA FORMATION.

The **Salina Formation** has been separated in this district into the following subdivisions:

Bossardville Limestone.
Rondout Waterlime.
Bloomsburg Red Shales and Sandstones.

BOSSARDVILLE LIMESTONE.

The Keyser or lowest member of the Helderberg in typical sections rests upon a flaggy, platy limestone named by Stose in the Pawpaw-Hancock Folio the Tonoloway Limestone from its exposures on the ridge of that name west of Cacapon River. Swartz (Md. Geol. Report on Lower Devonian, p. 109) suggested an apparent correlation of this limestone with the Bossardville Limestone of I. C. White* in Pennsylvania and New Jersey. It was named by White from Bossardville in eastern Pennsylvania where it has been extensively quarried for the manufacture of lime, and it was often described as the "ribbon limestone" from its banded appearance. It is described in that section as being in two divisions, an upper gray or bluish-gray to black massive limestone traversed by calcite streaks and without fossils, a lower division of dark-gray limestone with a peculiar banded or ribbon effect "produced by the edges of very fine layers of different colors, gray, whitish, blue, etc." It is described as nonfossiliferous in eastern Pennsylvania. On the Susquehanna,

*Second Geol. Survey of Penna., G6, pp. 141-5; 1885.

Lesley states the limestone contains the fossil *Leperditia alta* and that it is there 100 feet thick.

In Perry County, the limestone is described (Final Report, Vol. 2, p. 975) as "hard, dark, often bituminous and traversed by veins of calcspar. The weathered surfaces of the rock show that it is laminated, that is, composed of alternate darker and lighter very thin leaves or layers, which have no disposition to separate under the action of the air."

The lithological character of the Bossardville Limestone is very similar to the limestone called Tonoloway in the eastern Panhandle Area of West Virginia. In the same way it lies just below the Helderberg Limestone and in the same way is underlain by the so-called cement limestones. In West Virginia it contains the fossil *Leperditia alta* and in most of its ledges is almost non-fossiliferous. It differs in certain ledges that do contain a number of fossils. The Tonoloway thus agrees with the Bossardville in Pennsylvania in its lithology, its stratigraphic relation to overlying and underlying beds, and in its fossils. The latter being the older name and in use in the Pennsylvania and New Jersey Reports is used in this Report. The New York equivalent is at present doubtful. It resembles in fauna the Manlius or Tentaculite Limestone of that State. The correlation of the New York geologists would place the Manlius too high in the scale for this formation, as the Keyser Member of the Helderberg is apparently below the Manlius as placed by their work.

Ulrich in the Maryland Survey Report (p. 115) advances a classification in which he places the true Manlius below the beds referred to that group in New York and so below the Keyser Member. If this order is upheld the horizon of the Bossardville would be correlated with the Manlius. Until this question is definitely settled it would not be safe to correlate this group with the Manlius.

The **Bossardville Limestone** in Morgan and Berkeley Counties is composed of solid and shaly ledges, and in all typical outcrops there is a distinct fine banding of the stone, the ribbon effect described in the Pennsylvania Reports, and like the rock in those sections, it does not split along these planes on weathering.

In the typical locality of the Government Survey on Tonoloway Ridge, the limestone is very dark-gray to black, hard and compact, with a distinct banding, almost an agate effect, and breaks along joint-planes into slabby blocks. It tends to weather to a gray color. In some places it shows a layer of contorted breccia in a ten-inch seam, and contains as in Pennsylvania numerous calcite streaks some of which are one-half inch thick. Excellent exposures are made by the cutting of the river into this limestone near the gap in the ridge at Ziler Ford and opposite Rock Ford as well as between those two places.

In the Warm Spring Ridge the characters are similar with the ledges almost black in color and very flaggy. On Ferrel Ridge it is a gray to black limestone somewhat sandy and showing wavy banding, with a few fossils.

OUTCROPS. — The **Bossardville Limestone** outcrops along the east lower slope of Tonoloway Ridge across Morgan County to the Potomac River at Great Cacapon. The Cacapon River cuts into it from Ziler Ford nearly to Rock Ford where it forms the wall of the valley on west and in places on the east. It is well exposed in roadside cuts a mile south of Great Cacapon.

A belt of Bossardville Limestone follows the bottom slope on the west side of Warm Spring Ridge where it can be seen in various roadside cuts. Very good exposures are found in the railroad cut along the Potomac two miles southwest of Hancock Station. It has been quarried about four miles south of Berkeley Springs and burned into lime in a small one-kiln plant for agricultural lime.

A belt of this limestone surrounds Ferrel Ridge with a long narrow straight outcrop on the west slope and two belts of broader faulted outcrop on the east side of the ridge. It is opened in small quarries north of Jones Spring where it is burned into lime at the Wheeler kilns. These are the only outcrops of this limestone in this area.

Ulrich and Stose measured the following section of the Bossardville Limestone in the railroad cut along the Potomac east of Grasshopper Run about two miles southwest of Hancock (Pawpaw-Hancock Folio, p. 38):

Section of Bossardville Limestone near Grasshopper Run (Ulrich and Stose).

	Feet.	
Finely lamellar limestone interbedded with shale..	6	
Finely lamellar limestone weathering shaly........	85	
Shaly limestone, more shaly below................	58	
Massive thinly lamellar limestone, fine-grained, slightly argillaceous. Thick coral reef of *Stromatopora* and thin seams of crystalline limestone filled with ostracods, small brachiopods, and *Tentaculites gyracanthus* near base. Three of the ostracods are diagnostic of this zone but are undescribed species..............	143	
Magnesian limestone.............................	2	
Massive laminated limestone, *Tentaculites gyracanthus* and large *Leperditia*.....................	60	
Very thin-bedded limestone interbedded with thin shales	14	
Massive and thinly laminated limestones, some arenaceous. Containing ostracods and shells, *Hormotoma* (small species), *Rhynchonella? lamellata, R. litchfieldensis? R. hydraulica? Leperditia altoides*.................................	32	400

On the west slope of Ferrel Ridge toward the north end of the ridge and where the road crosses the ridge the following section was measured:

Section of Bossardville Limestone, Ferrel Ridge, Berkeley County.

	Feet.
Slabby bluish-black limestone with ledges ten inches.	15
Ledges more shaly and platy......................	35
Hard bluish-black limestone solid ledges break slabby	20
Very shaly ledge................................	3
Flaggy limestone................................	25
Slaty black limestone weathers blue...............	8
Solid ledges weather somewhat cobbly.............	15
Slabby limestone makes large plates a half to inch thick black weathers blue....................	20
Slabby limestone weathers with round concretionary masses..................................	20
Solid blue ledges but distinctly banded............	15
Concealed, but some slabby blocks show...........	45
Shaly bluish blocks with veins calcite, fossils....	20
Slabby limestone................................	25
More solid ledges weather bluish-gray............	8
Slabby ledges limestone..........................	28
Slabby limestone but weathers in more or less angular blocks..................................	15

	Feet.	
Gray fine shaly limestone with ridged surfaces slate-black color where unweathered, banded......	8	
Granular bluish-black limestone....................	8	350

Close-grained limestone, sandy, Waterlime beds.

Ulrich in the Pawpaw-Hancock Folio (p. 54) lists the following fossils from this limestone collected near Grasshopper Run and opposite Great Cacapon, and which he regards as equivalent to the late Cayuga or Salina rocks of New York:

From the lower portion of the limestone:

Stromatopora sp. undet.
Favosites globuliformis.
Fistuliporella, thinly lamellose species.
Cyphotrypa, new lamellate species.
Orthopora n. sp. (cf. *O. regularis*).
Schuchertella hydraulica var.
Meristella bella?
Whitfieldella nucleolata.
Rhynchospira globosa.
Rhynchonella litchfieldensis.
Rhynchonella hydraulica ?
Rhynchonella? lamellata.
Hormotoma sp. undet. (resembles *H. gracilis*).
Tentaculites gyracanthus.
Calymene camerata.
Leperditia alta.
Leperditia altoides ?
Beyrichia n. sp. (resembles *Entomis flabellifer* and *E. Oblonga*).
Kloedenia n. sp.
Bollia (*? Halliella*) n. sp.
Kloedenella clarkei.
Kloedenella halli.
Kloedenella (*? Tetradella*) cf. *hieroglyphica* (Krause).

From the upper 50 feet of the limestone:

Stropheodonta bipartita.
Spirifer corallinensis.
Spirifer eriensis.
Tentaculites gyracanthus.
Kloedenia cf. *nearpassi.*
Kloedenia sussexensis var.
Halliella ? cf. *seminulum.*
Primitia humilis?
Kloedenella clarkei.
Kloedenella (*? Tetradella*) *hieroglyphica.*
Octonaria n. sp.
Bythocypris cf. *concinna.*

THE RONDOUT WATERLIME FORMATION.

Below the Bossardville Limestone is a group of gray to light-buff thin shales and shaly limestones with some ledges of solid banded limestone from which natural cement was formerly made at Roundtop, Maryland, three miles southwest of Hancock, and also near Cumberland. The formation was named by Stose in the Pawpaw-Hancock Folio the Wills Creek Shale. Its relation to the overlying limestone and to the basal red shale and sandstone beds, also its cement character and the few fossils found are all similar characters to the Waterlime Formation or Rosendale of Pennsylvania and New York, and since the term **Rondout Waterlime** has long been applied to the formation it will be used in the present Report.

At the base of the formation is a heavy sandstone stratum, red in color, and weathers somewhat shaly and in places is almost a typical red shale. A similar group of red shales and sandstones in about the same stratigraphical position was named by Dr. I. C. White in Pennsylvania the Bloomsburg Red Shale. It was described as composed of red and green shales at Bloomsburg 440 feet thick and 325 feet in Huntingdon County. It extends through the middle portion of that State and was correlated with the Salina red shales of New York. The same formation is well exposed in the Morgan County area at a number of places. The top of the red sandstone and shale forming the Bloomsburg Member is taken as the base of the Waterlime Formation, so that it is readily determined in this area. The upper limit is not always easy to define. In many sections the Waterlime beds grade into the Bossardville but the latter is usually in more resistant ledges and darker color, while the Waterlime beds are more shaly.

In the Ferrel Ridge area, a heavy deposit of soft buff sandstone occurs near the top of the Waterlime beds, and it caps the minor ridges. In typical sections, Stose states there is a thin hard white sandstone near the top which shows in the Grasshopper Run Section seven and a half feet thick.

OUTCROPS.—The **Rondout Waterlime outcrop** follows along the valley to east of Tonoloway Ridge across Morgan County to the Potomac at Great Cacapon. Sections are almost impossible to measure on account of the weathered condition of the formation and the debris covering until followed across the river in the Western Maryland cuts. The Bloomsburg red sandstone member outcrops on the east side of the shaly limestones and its cliffs are well marked through the area.

The **Rondout Waterlime (Wills Creek beds)**, as defined by Stose, forms a well-defined outcrop, 800 to 1850 feet wide, to the west of the Bossardville west of Warm Spring Ridge with typical exposures in the Baltimore and Ohio Railroad cuts along the Potomac. The Bloomsburg Red Shale and Sandstone member at the base forms a very narrow outcrop to the west of the limestone, but at the north from opposite Prospect Rock on Cacapon Mountain north to about opposite Berkeley Springs the outcrop becomes much wider and then narrows to the Potomac. Good sections are exposed across the river in the railroad cuts.

The only other outcrop of this formation in Morgan or Berkeley Counties is on Ferrel Ridge where the slaty limestone and shales are well exposed but the Bloomsburg horizon is not exposed. The Waterlime beds there are found in two broad belts separated by a faulted zone of Bossardville Limestone, and the upper portion is very sandy with soft sandstones that have weathered to sand in most of the exposures.

Ulrich and Stose (Pawpaw-Hancock Folio, p. 39) measured the following section near the mouth of Grasshopper Run in the railroad cuts:

Section of Rondout Waterlime (Wills Creek) Formation at Grasshopper Run, Morgan County (Ulrich and Stose).

	Feet.
Greenish sandstone, fine-grained, in thick and thin plates	7½
Massive laminated magnesian limestone, weathering thin-bedded, with argillaceous beds weathering yellow. Fine oolite with *Leperditia* near base	45
Greenish shale and shaly limestone with thicker beds in middle and base. *Stromatopora* and ostracods at base. *Kloedenella clarkei, Leperditia alta?*	50
Shale and shaly limestone	60
Greenish impure calcareous sandstone with some rounded quartz grains	4
Shaly limestone and limy shale with thin sandy beds	15
Crumbly greenish shale with very thin sandy layers with *Leperditia*. Purplish shale and sandstone at base	100
Crumbly greenish shale and sandstone containing casts of salt crystals, *Leperditia* and small *Spirifer*	18
Red sandstone	1½

	Feet.	
Gray shale with casts of salt crystals and *Leperditia*, some red shale and a few thicker limestone beds	80	
Red sandy shale and yellow shale	15	
Bloomsburg Red Sandstone (52 feet).		
Massive-bedded, jointed red sandstone	10	
Hackly jointed red sandy shale	7	
Red jointed sandstone	5	
Alternating red shales and sandstone	30	445

Stose (loc. cit., p. 47) gives the following section of the Bloomsburg Red Sandstone member from the Western Maryland cut east of Tonoloway Ridge in Maryland and opposite Great Cacapon:

Section of Bloomsburg Red Sandstone Opposite Great Cacapon (Stose).

	Feet.	
Compact argillite or mud rock, green to gray in color in part finely laminated		
Green and red massive bedded argillite weathers crumbly and shaly.........40 feet.		
Jointed argillaceous sandstone, red and green banded and mottled	20	
Jointed red argillaceous sandstone in massive beds	20	
Red and yellow shale	3	
Jointed argillaceous sandstone, chiefly red, weathering to blocks	15	
Argillite, red and sandy above, green to bluish below	22	80

THE NIAGARA (McKENZIE) FORMATION.

Below the Bloomsburg Red Sandstone member is a group of shales and thin limestones resting upon a thick white quartzite. Stose in the Pawpaw-Hancock Folio gave to this whole group the name of McKenzie from its outcrop near a station of that name west of Cumberland, and he named the quartzite the Keefer from Keefer Mountain in Maryland.

There appears to be no name given to these shales and limestones in the former work of the Pennsylvania Survey, though Lesley states that (Final Report, Vol. 2, p. 839) "under these (Bloomsburg) red shales lie thin limestone layers separated by variegated shales making a gradual passage downward into the Clinton". The few fossils found seem to correlate it with the Salina. Under the Keefer member at one place to the east of Great Cacapon, Stose found a thin limestone with a fauna correlated with the Rochester Shale and Lockport Limestone of New York which he regarded as Clinton, but Pronty* not only puts these beds containing the Rochester fauna in the true Niagara, but also the overlying McKenzie, and this appears to be the correct correlation and the one the West Virginia Geological Survey adopts.

The outcrop of the McKenzie Formation is readily located in the field by the overlying red shale and sandstone of the Bloomsburg, and the underlying white Keefer hard quartzite.

Stose (p. 41) states that the Keefer Sandstone is composed of two sandstones separated by black shale, and that in its type locality at the south end of Keefer Mountain the lower sandstone is 15 feet thick, the upper is 25 feet separated from the lower by 15 feet of shale, or a total thickness of 55 feet. He gives the following section (p. 42) of the Keefer Sandstone from Lock 53 on the Canal six miles west of Hancock:

Section of Keefer Sandstone at Lock 53, Maryland (Stose).

Soft gray to yellow shale over the sandstone.	Feet.	
Hard white to gray sandstone, thick-bedded above, thin-bedded to shaly below....................	14	
Hard black fissile shale...........................	1	
Hard sandstone with rough surfaces, stained yellow and red......................................	10	
Hard black shale, sandy at top and pitted by rust-stained worm-tubes, containing abundant fragments of a eurypterid closely allied to *Hughmilleria socialis*..................................	6	
Irregularly bedded sandstone........................	7	38

Clinton Shales.

The following section of the **Niagara** (McKenzie) was measured by Ulrich and Stose at the mouth of Grasshopper Run in the railroad cut west from Hancock (loc. cit., p. 39):

*Pronty, Wm. F., The Meso-Silurian deposits of Maryland; Amer. Jour. Sci., 4th series, Vol. 26, pp. 563-574; 1908.

Section of Niagara (McKenzie) near Grasshopper Run, Morgan County (Ulrich and Stose).

	Feet.	
Blue shale with a few thin limestones with *Kloedenella*	25	
Gray subcrystalline limestone crowded with *Kloedenella* and rhynchonelloid shells	35	
Covered but in near by section seen to have dark shale near base and thin conglomeratic fossiliferous limestone beds above	70	
Keefer Sandstone. White quartzitic sandstone with *Scolithus* tubes, and interbedded hard black shale containing eurypterids	40	170

Stose measured the following section of the Niagara (McKenzie) (p. 40) across the river in Maryland from Great Cacapon but the basal member was not exposed:

Section of Niagara (McKenzie) Opposite Great Cacapon, in Maryland (Stose).

	Feet.	
Bloomsburg Red Sandstone.		
Shale, red at top, green below	10	
Green to yellow and red shale, soft and weathers to fine fragments, somewhat crumpled	80	
Contorted interbedded olive to drab fissile shale and beds 1 to 2 inches thick of fossiliferous gray subcrystalline limestone. Limestones thicker and more numerous in lower portion	70	
White sandstone, Keefer Member (not exposed here)	40	200

OUTCROPS.—The **Niagara (McKenzie) Formation** is found in but two outcrops in Morgan County and is not exposed in Berkeley County. It forms a belt just east of the Rondout Waterlime east of Tonoloway Ridge and east of the Cacapon River. It is marked on the west by the Bloomsburg Red Sandstone outcrop and on the east by its Keefer Sandstone Member which extends north past Rock Ford to Great Cacapon Station. Southeast of town on the river bank, it is closely folded in ridged folds known locally as the "fluted rocks".

The other belt is to the east of Cacapon Mountain with the Keefer Sandstone on the west, and the Bloomsburg outcrop on the east. The Keefer member caps a number of low ridges and over most of its exposure forms a narrow band, but back of Roundtop it expands covering a broad area on the hill to the south. This formation is not exposed on the Ferrel Ridge Anticline.

Stose gives the following list of fossils collected from this formation by him and Ulrich in the Western Maryland cuts opposite Great Cacapon (p. 44), and they are correlated by them with the Salina Formation:

Dalmanella postelegantula.
Trematospira n. sp. (near *T. camura* and *T. perforata*).
Whitfieldella n. sp. (*near W. nitida*).
Spirifer n. sp. (*near S. sulcatus*).
Spirifer cf. *eriensis.*
Rhynchonella formosa.
Rhynchonella cf. *vellicata.*
Rhynchonella n. sp. (very finely plicated).
Uncinulus cf. *pyramidatus.*
Ctenodonta n. sp.
Cleidophorus cf. *Nucula sinuosa* Simpson.
Prothyris n. sp. and other pelecypods.
Coleolus sp. undet.
Orthoceras, 2 species undet.
Beyrichia moodeyi.
Kloedenia cf. sussexensis.
Two undescribed species of *Kloedenella* and prenuntial varieties of *K. pennsylvanica, K. turgida, K. clarkei.*

THE CLINTON FORMATION.

Below the Keefer Sandstone of the Niagara (McKenzie) Formation is a group of fine platy buff and reddish-buff shales with small red sandstone ledges correlated with the Clinton of New York and Pennsylvania. Iron ore ledges are found in the formation, and the ore was mined at one time back of Sir Johns Run Station, but it was too low in iron and too high in silica to be profitable.

OUTCROPS.—A belt of Clinton is found along the western base of Cacapon Mountain in a narrow outcrop at the south end, but at the Rock Ford on Cacapon River it widens from about 700 or 800 feet to nearly 4,000 feet. It then extends north to the Potomac River.

Another belt is found along the eastern base of this mountain and extends north in a belt of rather uniform width, 800 to 1,000 feet. It bends around the north end of the mountain, joining the western belt with a total width of 4,000 feet. The crest of the mountain exposes the Clinton Shales and the

Red Sandstone at a number of places from a point a mile south of Prospect Rock on the south.

A narrow belt of Clinton is found on the western upper slope of North Mountain, north and south from Hedgesville. It is there composed of fine, flaky, buff shales, and platy and angular blocks of coarse-grained red sandstone. This belt extends nearly the full length of the mountain, but it is faulted out near the Potomac.

The Clinton is in many sections very fossiliferous. Stose gives in the Pawpaw-Hancock Folio the following list of fossils collected in the Sir Johns Run locality:

Dalmanella elegantula var.
Stropheodonta corrugata.
Stropheodonta prisca.
Chonetes sp. undet.
Atrypa? gibbosa.
Anoplotheca hemispherica.
Whitfieldella intermedia.
Camarotoechia neglecta.
Tentaculites n. sp.
Concularia niagarensis.
Bollia lata.
Beyrichia, 2 species.
Calymene clintoni.

THE MEDINA FORMATION.

The White Medina Sandstone or quartzite of Pennsylvania and New York has been called by the United States Geological Survey, without any sufficient reason, the Tuscarora Sandstone. It is in this area of West Virginia a very hard, white, close-grained sandstone, almost a quartzite, and very resistant to weathering action. It forms the crests of Cacapon and North Mountains.

OUTCROPS.—Cacapon Mountain from its northern end south to Prospect Rock, which is a high cliff of this sandstone, is covered by the White Medina Sandstone, which also forms its east and west slopes south across Morgan County. The slopes are very steep, often a vertical wall of rock and practically inaccessible at such places. It again comes to the surface in a small outcrop along the river bluff just west of Sir Johns Run Station.

The White Medina forms the crest of North Mountain in a long, narrow outcrop from the Potomac River south across Berkeley County. It is apparently faulted out near Hedgesville, but outcrops both to the north and south of this place.

The thickness is given by Stose as 100 to 200 feet on North Mountain, and 250 feet on Cacapon Mountain.

Below the White Medina Sandstone is a **red sandstone** with red sandy shales which appears to correspond to the **Red Medina** of Pennsylvania, and which has been renamed by the U. S. Geological Survey, the Juniata Formation. It is without fossils, but sandstones further south in Virginia and Tennessee correlated with this group contain fossils of Ordovician age. This red sandstone is found in this area on the west slope of Cacapon Mountain in deep ravines where it has been exposed by deep erosion in scattered outcrops.

It also outcrops on the upper east slope of North Mountain in a long, narrow belt from the river south. It contains a conglomerate bed to the south of Hedgesville, and is cut out in the Hedgesville gap. On the maps with this Report, this sandstone is included with the White Medina. Its thickness on North Mountain, according to Stose, is about 200 feet.

CHAPTER XI.

THE ORDOVICIAN PERIOD.

THE SUBDIVISIONS OF THE ORDOVICIAN.

The Silurian System, as identified in the early days of English geological field work by Murchison, was divided into two groups — The Upper and The Lower. On account of the importance of both groups, Lapworth in 1879 proposed limiting the name Silurian to the upper division and giving to the Lower a new name, Ordovician, whose origin like that of the Silurian was derived from the name of old Celtic tribes in the mountain area of Wales, and this new name is now in general use in the United States.

As in the case of the Devonian and Silurian periods, the early work in this country on the Ordovician was in New York State and locality names in that State were given to the subdivisions and they are regarded as standard over the country. The early classification of the Ordovician was into five groups:

Hudson River Shales.
Utica Shales.
Trenton Limestone.
Chazy Limestone.
Calciferous Limestone.

Later and more detailed work in that State by Clarke and his associates on the State Survey has modified this classification to some extent and has enlarged it as shown in the following table based in Professor Clarke's Handbook (No. 19) of the New York State Museum:

> Lorraine Shales (Hudson River).
> Utica Shale.
> Trenton Limestone.
> Black River Limestone (including
> the Lowville or Birdseye).
> Chazy Limestone.
> Beekmantown Limestone (Calciferous).

Clarke states that the Hudson River Shale Group as originally marked by Mather in 1840 in reality includes horizons of the entire Ordovician, and the later name of Lorraine proposed by Emmons in 1842 is more appropriate for this formation. It consists in New York of shales and sandstones that have a thickness of 700 feet in western New York and with much greater thickness in the eastern part of the State. Dana states (Manual of Geology, p. 492) that a boring near Utica passed through 3440 feet of Hudson River and Utica Shales. These shales extend westward into Ohio and Indiana where they are usually known as the Cincinnati Group. They extend south across Pennsylvania, Maryland, and West Virginia into Tennessee where the thickness is reported as 2000 feet. In New York geology, the name Lorraine is now substituted for Hudson River. Below this group of shales is the Utica, named from that city in New York, which also has a wide distribution, but is often difficult to separate from the Lorraine when fossils are absent.

Below the Utica is the Trenton Limestone named from Trenton Falls, which is a most important oil and gas horizon in Ohio and Indiana, and is represented in Illinois and Wisconsin by the Galena Limestone, an important source of lead and zinc. Southward from New York it is not so well developed and can only be identified in Maryland and West Virginia by its fossils.

The Black River Limestone in New York originally applied to a very thin limestone along the river of that name, but was later used to include a number of other limestones. As now used it includes the Lowville or Birdseye Limestone of New York and which has been traced south through Pennsylvania into Maryland and West Virginia.

The Chazy, named from a village in Clinton County, is a black or gray limestone and marble in a small area, but in part equivalent to the Stones River of the south. The Stones River Limestone is found over a large area in Tennessee, Virginia, West Virginia, and Maryland. It extends into New York, according to the studies of Cushing (Bull. Geol. Soc., Vol. 19, p. 155) near Watertown, where it is represented by his Parmelia Group of blue- and dove-colored limestones.

The Beekmantown Limestone formerly known as the Calciferous was first described as a grayish magnesian limestone sandy and cherty with very few fossils.

The Ordovician section as exposed in the eastern Panhandle area of West Virginia may be divided into the following groups:

Martinsburg Shale. { Lorraine. / Utica. / Trenton.
Chambersburg Limestone (Black River in part).
Stones River Limestone (Chazy in part).
Beekmantown Limestone.

THE MARTINSBURG SHALE.

The upper portion of the Ordovician in Berkeley and Jefferson Counties, West Virginia, is represented by a group of shales named by Darton, the Martinsburg Shale. Darton states (Amer. Geol., Vol. X, p. 13) that these shales

"Succeed the Shenandoah Limestone with a thin series of alternating thin-bedded limestones and slates at their base. The name is taken from Martinsburg, in the Shenandoah Valley, in West Virginia, a region in which the formation is extensively and typically exposed. . . . The rocks are slates and shale, mainly of dark color. . . . The beds are fossiliferous at many points; graptolites are found in the basal beds. Along Little North Mountain, and in the Warm Spring, Crab Bottom, and other anticlinal valleys westward, remains of Upper Ordovician brachiopods are moderately abundant. The forms most frequently met with are, *Leptaena sericea*, *L. alternata*, *Orthis testudinaria*, *O. pectinella*, and *Modiolopsis modiolaria*. The precise equivalency of the formation is not known, but judging from its general relations and fauna, it probably comprises the Utica, Hudson River, and possibly small amounts of adjacent formations of the New York series. It is No. III of Rogers' reports and has generally been called the Hudson River."

The Martinsburg Shale near its contact with the underlying limestone is very calcareous in blocky ledges grading

PLATE XVII.—Detail of Anticline and Adjacent Syncline of Fluted Rocks on Cacapon River. (Photo from Pawpaw-Hancock Folio of U. S. Geological Survey).

into the limestone, with black very hard limy shales above and which weather to buff small blocky shale. Still higher the shales have à purplish-black to dull-black color and weather to buff smooth platy shales and finally to a shale gravel. Some of the ledges weather to long slender prisms or pencils and on less weathered outcrops show a tendency to spheroidal weathering. The shale is cut by numerous joint-planes in three sets at right angles to each other and various diagonal planes so that the ledges break into small plates more or less angular. The shales are crumpled and folded.

The surface buff shales as followed downward in new exposures at brick-yards, railroad cuts, stream valleys, etc., soon pass into hard black shales or slates which break out in large irregular blocks almost like a limestone, but they will split along parallel planes like a roofing slate. Such exposed rock has every appearance of durability but in a short time on exposure slacks and falls to pieces with a fading of the black color to a greenish-black then to a brownish-black and finally buff flaky shales. According to Dale (Bull. U. S. G. S., p. 275) the cleavage in these slates is due to parallel arrangement of lime and carbonaceous material in parallel bands and they are to be classed as clay slates rather than mica slates. Chemically these shales contain 53 to nearly 58 per cent. of silica, and 18 to 20 per cent. alumina with about 5 per cent. of lime oxide.

In the upper portion of the formation beds of sandstone occur and the shales are more sandy. In these upper shales minute mica scales or points are seen and there is a tendency to weather to more block shales than in most of the lower beds which are more flaky.

OUTCROPS.—The outcrops of Martinsburg Shale are found in Berkeley County to the east of North Mountain, and in the eastern part of the county and in southwestern Jefferson County.

Just east of the mountain a long outcrop extends from three-fourths mile south of the Potomac River north of North Mountain Station, southwest along the foot of the mountain to the Virginia Line. It is a very narrow belt near North Mountain Station and Hedgesville with an average width of

1,000 to 1,500 feet at the north, 3,000 feet west of Arden, and over a mile wide from north of Gerrardstown to the State Line.

This shale makes a good red brick at the plant near North Mountain. In the railroad cut north of this plant, the shale is faulted against the Helderberg Limestone and Marcellus Shales, while further north it is faulted out between the Elbrook and Medina. Its thickness at the brick plant is about 750 feet. Through this area it is a fine flaky buff shale in all surface exposures, and bluish-black, compact shale breaking with smooth surfaces in the deeper cuts at the brick works.

North of Gerrardstown, the shales are in many places purplish-black in color and quite hard, while further north occur brownish-buff sandstone ledges, some of which are ten feet thick, also very sandy shales. The purple-tinged shales are well exposed to the west of Gerrardstown in the road cuts, where they are much crumpled and contorted. Buff and purple-black shales are found on the roads to the south of this town. On weathering the shales are buff, flaky, and more or less marked with white kaolin streaks giving an ashy appearance.

The main belt of Martinsburg Shale is in the eastern part of Berkeley County and extends from the Potomac in the extreme northeastern corner of the county southwest to the Virginia Line. This broad belt is bounded on the eastern and western sides by the Chambersburg Limestone, and it is a broad synclinal fold, broken by much minor folding. Anticlines through it bring to the surface the Chambersburg and Stones River Limestones here and there in elongated lenticular outcrops. The width of the outcrop at the north is two and three-fourths miles, and it is about the same to the east of Martinsburg, but further south it is four miles. In the southern part of the area, the outcrop of shale is divided by a fold of Chambersburg Limestone into a broad western portion to the west of Opequon Creek, and a long narrow eastern tongue in Jefferson County to the east of the creek.

The shale area in these counties is marked by rounded hills with steep slopes, cut by narrow, deep ravines. Where the land is not cultivated, it is covered by a growth of stunted pines and cedar, and the country is designated as the "pine hills". By cultivation the shales are weathered to a fine flaky, er blocky soil of shallow depth, which with abundant moisture yields good crops. A large portion of the northern area of outcrop and the borders of the whole outcrop near main roads, are cultivated. Near the center of the belts of shale away from the main roads, a very large acreage is not worked and it is practically waste land.

The roads across this shale area when kept in repair are smooth and solid in good weather, but become very muddy and rough in bad weather. When not kept in repair, these roads are filled with ruts and holes, and become types of bad roads. The road cuts and deep ravines show good sections of the shale which in weathered outcrop is usually buff in color, and in flaky plates, small blocks, or pencil prisms. In the deeper cuts, it is purplish-black to black in color, and is then a very hard, compact slate. Often the shales have a bluish or olive-green color. Spheroidal weathering is common and may be observed in almost any large bank which has long been exposed to the weather. This feature is well developed in the Cumberland Valley Railroad cuts near Falling Waters, in the deep county road cuts near Opequon Creek on the Schoppert Ford and also the Charlestown roads from Martinsburg east.

In the Baltimore and Ohio Railroad cuts east of Martinsburg, the shales are much weathered, but show here and there purplish-gray to black-colored shales. The weathered shales here are platy, flaky, and very fissile. Two miles east of town on the railroad and near the county road crossing, spheroidal weathering is developed, and the shales have a gray or ashy-white surface. The same weathering is seen in this section in road cuts.

Back of Van Clevesville the shales are very sandy and there are outcrops of angular, blocky, buff sandstone in ledges two to ten feet thick. These sandstones and sandy shales outcrop to the east of Marlowe and to the southeast of that place; also to the west of Leetown near Egypt; and in the southern part of the county east of Ridgeway beyond Paynes Chapel; and further east on the hills above Opequon Creek. These sandy ledges outcrop down the creek at Middle Branch and up this run. The sandy shales and sandstones, usually quite soft, are found in many places over the shale area, but they are usually so much weathered that they are only sandy fragments or very brittle blocks of loose sand with very minute points of mica, and some white clay particles.

The shales are usually very much folded and contorted. with slaty cleavage, and joint-planes well developed. The dip changes rapidly in amount and direction over short distances. It is almost impossible to make any complete sections and the real thickness of the formation is not known. The thickness near Opequon Creek east of North Martinsburg and a mile north of the main line of the Baltimore and Ohio Railroad, appears to be about 2,400 feet; and two miles south of this place, it appears to be about 3,000 feet. The minor folding makes any measurements doubtful, but the thickness in this area is probably around 2,500 to 3,000 feet.

CORRELATION.—These shales are only sparingly fossiliferous, whole sections appear to be without a trace of fossils, while a few strata contain fossils but usually in small number. In the basal beds not far above the Chambersburg Limestone, graptolites are found, a few fragments of trilobites, and rarely a few brachiopods.

Stose (Pawpaw-Hancock Folio, p. 29) gives the following list of fossils in these basal beds near Martinsburg and Chambersburg:

Corynoides calycularis.
Glyptograptus sp. nov.
Climacograptus spinifer
Leptobolus insignis.
Schizocrania filosa.
Cyclora minuta.
Trinucleus concentricus?
Climacograptus cf. *hughesi.*
Triarthrus becki.

These fossils were regarded by Ulrich as of Lower to Middle Trenton age. Above this horizon, given by Stose as 100 feet in thickness, is a series of buff, somewhat micaceous shales, apparently without fossils, usually correlated with the Utica of New York.

In the upper, more sandy shales with included sandstones, some fossils are found. Stose gives the following list of this fauna:

Dalmanella multisecta.
Plectambonites sericeus.
Zygospira modesta var.
Orthoceras transversum.
Callopora sigillaroidea.
Calymene callicephalus.

Ulrich regards these forms as characteristic of the Eden and lower part of the Lorraine of New York and the Cincinnati sections.

The Martinsburg Shale, therefore, includes fossils of the Trenton, Utica, Eden, and Lorraine of the New York and Ohio sections. These groups can be separated in this area at only a few typical exposures where fossils are found, and it would be impossible to map the separate formations over the outcrop area in the field, and hence the name Martinsburg Shale is retained.

THE CHAMBERSBURG LIMESTONE.

Below the Martinsburg Shale is a group of limestones in the Shenandoah Valley which was named by Darton the Shenandoah Limestone and described as "a great mass of impure magnesian limestones below, grading upwards through a series of cherty beds of no great thickness into several hundred feet of light-colored heavily bedded pure limestones. The lower beds were not found to be fossiliferous. . . . The upper member is sparingly fossiliferous at many localities with a middle to upper Ordovician fauna." (Amer. Geol., Vol. X. p. 13).

Prosser (Jour. of Geol., Vol. 8, p. 662; 1900) states "There seems to be no question but that the upper part of the Shenandoah Limestone is correctly correlated with the Trenton Limestone. The lower part of the Shenandoah Limestone contains Cambrian fossils but the line of division between the Cambrian and the Lower Silurian, which apparently is not indicated by any physical break, has not yet been determined in the Great Valley."

It is only in the past few years that any serious attempt has been made to separate this complex of Shenandoah Limestone, but through the work of Stose, Ulrich, and Bassler of the U. S. Geological Survey, the Ordovician has been separated from the Cambrian, and a number of divisions can now be traced and mapped in this area.

The upper member of the Shenandoah Limestone Group just below the Martinsburg Shale was named by Stose

(Mercersburg-Chambersburg Folio) from its exposures near Chambersburg, Pennsylvania, the Chambersburg Limestone, and it contains fossils of the Lowville and Black River of New York, but as has been stated in a previous paragraph the New York Survey now includes the Lowville under Black River.

Below the surface this limestone in the eastern Panhandle area is a dark-gray or blue to black hard granular rock marked by calcite streaks and crystals often along the joint-planes. The ledges break along parallel planes forming flaggy outcrop at many places. The surface layers are crossed by bands of clayey material in irregular lines so that on weathering the stone breaks into rounded and angular fragments forming a cobblestone effect. This cobbly weathering is very characteristic of this limestone and its weathered outcrop is often a mass of such pebbles or cobbles. The black stone weathers to a gray or bluish-gray color seamed by yellowish clay bands. The upper beds in some exposures are quite shaly and weather to a calcareous shale grading into the lower divisions of the Martinsburg Shale.

Stose gives the following section of this limestone at its type locality at Kauffman, near Chambersburg, Pennsylvania, (Journal of Geol., Vol. 16, p. 710), which he states is the most complete, continuous section in that area:

Section of Chambersburg Limestone near Chambersburg, Pa. (Stose).

	Feet.	
Largely concealed, but probably shale (near top black, carbonaceous limestone with conchoidal fracture, shaly, dark, crystalline limestone, thin sandstone, and ten feet of coarse, crystalline limestone containing Lingulas)................	150	
Calcareous shale and limestone..................	100	
Nodular clayey limestone........................	50	
Dark, platy limestone...........................	94	
Compact, dark limestone, very fossiliferous........	108	
Cobbly limestone containing numerous Nidulites, Bryozoa, and a layer of Cystid heads...........	105	607

OUTCROPS.—The Chambersburg outcrops are found in the eastern portion of Berkeley County and southwestern part of Jefferson. They are usually long and narrow, except near the ends of folds where the low dip of the strata gives a broad surface outcrop.

The most western outcrop is a long narrow belt extending from the Potomac River at Millers Bend southwest past Martinsburg and Bunker Hill to the Virginia Line . The width of this outcrop is 500 to 800 feet. South of Martinsburg by folding, there are places where the width is nearly 4,000 feet over a short length. It is about 800 feet wide at the south line o' the county.

The Chambersburg Limestone outcrops on both sides of the anticlinal fold east of Opequon Creek from opposite Bedington thence south to a mile south of the main line of the Baltimore and Ohio Railroad. West of Bedington, there is a long outcrop broad at the north and narrowing southward, which is partly broken at the north by the shale and the Stones River Limestone. Another long anticline of Chambersburg Limestone runs north and south, to the east of Bedington, extending two miles north of the Potomac, and two and three-fourths miles south of the river, with a width of 1,200 feet at the north, and 1,500 feet in the widest part, which is just northeast of Bedington.

A long narrow outcrop extends from the Potomac near the mouth of Opequon Creek, southwest past Van Clevesville and Middleway, and it is faulted out to the south of the latter town. Near the Van Metre Schoolhouse, a mile and three-fourths southwest of Van Clevesville, a synclinal fold makes two parallel outcrops for a few miles.

West and northwest of Middleway is a broad area of Chambersburg Limestone extending south in narrow outcrops, one of which extends beyond the State Line. In the southwestern corner of Jefferson County, east of Opequon Creek, an anticlinal fold exposes the Chambersburg Limestone in the shales in two belts.

The thickness of the Chambersburg across the Opequon, one and a half miles southeast of Bedington, is 515 feet, as shown by the following section:

Section of Chambersburg Limestone near Opequon Creek.

Martinsburg Shale.	Feet.	
Bluish-black, foliated limestone	145	
Dark-blue limestone, breaks in small cobbles	150	
Bluish-black limestone in thin ledges, cobbly	100	
Cobbly limestone in 4- to 8-inch ledges	120	515

South of Martinsburg and east of the Standard Limestone Company quarries, the thickness of the Chambersburg is 480 feet, and the thickness is about the same east of the National quarries. Near Van Clevesville, the thickness is 420 feet. Near Berkeley Station four miles north of Martinsburg, a good section of the Chambersburg is exposed in the cut of the connecting switch from the Baltimore and Ohio Railroad. At this place the thickness is 575 feet.

Section of Chambersburg Limestone near Berkeley Station.

Martinsburg Shale.	Feet.	
Bluish-black shaly limestone in 4- to 8-inch ledges	22	
Bluish-gray, irregularly seamed limestone, cobbly	35	
Solid ledges, dark-blue limestone, calcite streaked	54	
Solid ledges but breaks in thin courses	54	
Cobbly limestone, dark-blue to black	27	
Solid ledges but wavy lined, breaks to angular blocks	52	
Cobbly dark-blue limestone	24	
Ledges break in thin courses, weathers cobbly, fossils	82	
Solid ledges breaking in thin courses, some fossils	27	
More compact, dark-blue limestone, wavy lined	80	
Platy and blocky ledges, with fossils	25	
Very cobbly ledges, some fine breccia, and fossils	27	
Cobbly ledges and very small breccia	66	575

The upper 268 feet of this section is of limestone ledges that appear to be almost non-fossiliferous, while the lower 307 feet contains limestones with abundant fossils. The cobbly weathering is found throughout the formation. Most of the ledges are thin and the bedding very uneven, but some ledges are solid and could be used as building stone. This solid character is shown in the small quarry near the railroad northeast of Falling Waters.

CORRELATION.—Many of the ledges of the Chambersburg Limestone are very fossiliferous, but the limestone is so hard and breaks so irregularly that it is very difficult to collect these forms from the rock. They must be identified in the field. Stose and Ulrich describe over 130 species in the Chambersburg, Pennsylvania, area, and about the same number in the Mercersburg area.

They separated the formation by its fossils into five faunal zones. The lower or Tetradium and Leperditia zone, which is regarded by Ulrich as the representative of the Lowville of New York. The second is the Echinosphærites zone, probably equivalent to the Black River horizon of New York. The third or Nidulites zone and the fourth or Christiana zone, with a thickness of 600 feet in the Pennsylvania area, Ulrich regards as lying between the top of the Black River, and the base of the Trenton of New York. The fifth or Sinuites zone is placed with the Martinsburg Shale Formation by Ulrich who correlates it with the Normanskill division of the New York Trenton.

Ulrich found that at Martinsburg, the lower, or Lowville, horizon was absent, while the Echinosphærites zone had a thickness of 20 feet; the Nidulites zone was 300 feet; and the Christiana zone was 20 feet, so that the greater portion of the thickness of the Chambersburg in this area belongs in the third or Nidulites zone.

The Chambersburg Limestone thus includes several distinct New York Formations, and most of it appears to be above the Black River horizon and below the Trenton. The name Chambersburg Limestone is given for this formation by Stose on account of the good outcrops near that place.

STONES RIVER LIMESTONE.

Below the Chambersburg Limestone in the eastern Panhandle area is a series of light bluish-gray to dove-colored limestones often of a very high degree of purity, and quarried on a large scale for fluxing stone as described in a later Chapter of this Report. These high-grade ledges are underlain by magnesian limestones, dolomites, and high carbonate of lime rock. All of these limestones are grouped under the Stones River Formation, which may be separated into three divisions —Lower, Middle, and Upper. This formation usually outcrops in a valley due to its solution, and this is especially true of the Upper division.

The Upper Stones River Limestone in this area includes very pure limestone strata. The stone is compact, breaks with shelly or conchoidal fracture into masses or blocks, and it is very brittle, breaking like a piece of glass. The stone is often marked by calcite spots and strings, giving a bird's-eye effect. The rock in its pure form has a dove or creamy-white color. In other ledges it has a bluish tinge with no trace of calcite. It is sometimes mottled, and again has a very saccharoidal or sugary texture. Some nearly black ledges break with the smooth shelly fracture and on analysis prove very pure. This dark color burns out in the kiln, and it is probably due to organic matter.

The purity of these ledges is remarkable. Analyses made over a thickness of a hundred and fifty feet show less than half of one per cent. silica. Analyses made through the length of the outcrop for twenty miles show the same result, with 97 to 98 per cent. carbonate of lime. Car-loads have been shipped that average over 99 per cent. carbonate of lime with but a trace of silica. In some quarries there appears to be an increase of silica from the top to the bottom of the quarry.

The surface outcrop by weathering shows a fluted character, pitted and furrowed by water solution. The outcrop usually projects in pinnacles and knobs, the hollows being filled with residual red clay. When this clay is removed by quarry stripping, the surface is a series of towers and turrets, a most irregular outcrop. The cover is usually this red clay which extends in fissures to great depths parallel to the bedding-planes. The rocks are usually highly tilted and folded. This folding brings in double lines of outcrops in many places. South of Martinsburg, the east and west belts at the Standard Lime and Stone Company quarries are on the east and west sides of a pitching anticline. The same is true of the two belts on the National Limestone Company property, and also at the Blair Company quarries. These anticlines pitch to the north and to the south, often disappearing from the surface completely under the Chambersburg Limestone. Tl fold may rise again, bringing the good limestone to the surface as is seen south of the Standard quarries.

The width of the surface exposures of the high-grade limestone of the Upper Stones River in the Martinsburg area varies with the amount of dip. It runs from ten to a thousand feet. The thickness of the Upper Stones River Limestone west of Falling Waters is 200 feet, with a width of outcrop of 360 feet. It is 180 feet thick on the outcrop three-fourths mile west of the last locality. The thickness at the Potomac River northwest of Falling Waters is 180 feet. South of Martinsburg the thickness is 160 to 185 feet, with a width of outcrop of 250 to 350 feet, and in a few places the plungin end of an anticline gives a width of a thousand feet. Fossils are rarely found in the Upper Stones River Limestone except the tubes and sections of *Tetradium* which are very common in some ledges.

The Middle Stones River includes more siliceous and more magnesian limestones, dolomites, with ledges which are fairly pure and resemble the Upper member, but they run higher in silica. The color is usually dark bluish-gray to nearly black, and the rock is often banded or striated. Brecciated ledges are common, also bands of very compact, dark-colored limestone. Some of the dolomites have almost theoretical proportions of magnesium and lime carbonate, but they are usually high in silica. They are light-gray in color and form heavy, blocky ledges. Black flints are common in many outcrops. Some of the strata are very fossiliferous and are filled with broken segments, or more rarely complete forms of *Maclurea magna* which is characteristic of the middle Chazy Limestone of New York. Brachiopods and Gasteropods are also common. There is a sharp contrast in composition and appearance between this division and the Upper, so that the separation is readily made.

The Lower Stones River Limestone is usually dark-blue, banded or striated, often breaking into slabby ledges. It runs usually high in magnesia and it is also high in silica. Near its top at the Bunker Hill quarries, a well-defined cone-in-cone structure is developed. It grades into the Middle division, and the line between them can not be drawn closely, but the lighter-gray color of the Middle division appears to be absent in the Lower. The base of the Stones River Formation is taken at the cauliflower chert horizon at the top of the Beekmantown, which can readily be followed in this area.

In the Chambersburg, Pennsylvania, region, Stose gives the following composite section of the Stones River Limestone (Jour. of Geol., Vol. XVI, p. 708):

	Feet.	
Thin-bedded, fine-grained, pure dove limestone.....	275	
Massive pure limestone with *Maclurea magna* and black chert layers. Upper part compact, blue to dark; lower part, light-gray, granular and oolitic 150 to..................................	200	
Massive and thin-bedded limestone interbedded with magnesian layers..............................	600	1050

The following sections of the Stones River Formation were measured in the Berkeley County area. The first was taken at the Pittsburgh Limestone Company quarries, two miles and a half north of Falling Waters, on the Potomac River:

Section of Stones River Limestone at Potomac River.

	Feet.	
Upper Stones River (184')		
Light-gray, very pure limestone....................	50	
Light-gray, with bird's-eye calcite..................	5	
Light-gray pure limestone with some small breccia..	15	
Black slaty limestone with films of black coaly material	2	
Light-gray pure limestone..........................	12	
Bluish-gray pure limestone........................	15	
Bluish-gray, slightly foliated, calcite streaks........	25	
Light-gray, somewhat banded, pure limestone.......	50	184
Middle Stones River (205')		
Gray limestone with numerous *Maclurea magna*, and shells	100	
Blue and gray limestones, some banded.............	60	
Blue limestone, bird's-eye and calcite streaks.......	24	
Compact limestone, blue, with calcite plates, fossils	20	

	Feet.	
Bluish-gray, magnesian limestone with breccia at top composed of white limestone pebbles parallel to bed	6	
Light-gray limestone fairly pure	5	205
Lower Stones River (344′)		
Blue dolomite, compact and banded	16	
Dark-blue dolomite with inclusions of softer limestone with irregular outline, calcite streaked	48	
Hard compact limestone with irregular fracture	15	
Bluish-gray limestone banded and breaks flaggy	11	
Shaly limestone weathers to shales	2	
Compact dark-blue limestone with nodular black flint concretions, 10 by 4 inches in size in lower portion	10	
Bluish-gray dolomite, compact, with black bird's-eye (½ to 1″)	9	
Irregular blocky ledges of blue-gray, hard dolomite	33	
Dark-blue dolomite, some veined, other ledges compact	100	344
Total thickness of Stones River		733

In this quarry section along the river bluffs, the rocks are well exposed from the top of the formation down. At the base, the cauliflower chert horizon was not found, so that it is possible that the Lower Stones River may have somewhat greater thickness than given above. It is also very doubtful if the top of the formation was reached in this section. The working quarry is in both the Upper and Middle Stones River. This is the only locality in the Martinsburg district where the Middle division is used. Fossil shells are very abundant in this Middle division at this quarry, especially the *Maclurea magna.* The bird's-eye effect of the calcite spots is quite characteristic in the Upper division. The black flint horizon of the Middle portion was not observed here, but in the Lower division at one place were large balls of black flint elongated, and different in appearance from the black flint of the Middle series.

Seven miles south of the Potomac quarries and east of Opequon Creek across Myers Bridge, a section of the Stones River shows an increased thickness of the Middle division, while the Lower division is apparently absent. In the Middle series are some very low silica limestones, which are separated from the Upper by a belt of higher silica, flaggy ledges:

Section of Stones River Limestone near Mouth of Opequon.

	Feet.	
Chambersburg Limestone.		
Upper Stones River.		
Light dove-colored limestone, shelly fracture....	120	
Middle Stones River.		
Light-gray limestone weathers slabby..........	125	
Fairly pure limestone light-gray..............	50	
Light-gray limestone full of Gasteropod shells..	150	445

A section of the Stones River south of Martinsburg at the Standard quarries shows the three divisions, but the Lower has decreased in thickness from that at the Potomac quarries, while further east at the National quarries on the east side of the anticlinal fold, the Lower division is absent and the Middle is very thin, with the Upper division well exposed. The same condition is found at the further south Standard quarries, so that the cauliflower chert horizon is close to the outcrop of the Upper Stones River. On the west side of the anticlinal fold at the National quarries, the Upper division is thin with a good development of the Middle division.

Section of Stones River Limestone South of Martinsburg.

	Feet.	
Upper Stones River.		
High-grade, pure, dove-colored limestone............	160	
Middle Stones River.		
Bluish-gray, hard dolomite.........................	100	
Blue limestone, more or less banded...............	90	
Light-gray fairly pure limestone..................	25	
Blue limestone, rather compact....................	60	
Bluish-gray limestone with some black flints.......	245	680
Cauliflower chert horizon of Beekmantown.		

The Upper Stones River Limestone at the National quarries reaches 195 feet in thickness.

The Upper Stones River Limestone has been extensively quarried in the Martinsburg district for many years and a large tonnage of this low silica limestone flux is shipped daily to Pittsburgh and other steel centers.

Ten miles south of Martinsburg near Bunker Hill, the J. E. Baker Lime Company quarries are opened in the Upper Stones River. The cauliflower chert horizon in the Beekmantown here has a thickness of 65 feet, and above it is a series of gray to blue limestones and dolomites, with black flints well shown, also brecciated ledges, comprising the Middle division. The Lower is absent, and the total thickness is greatly reduced over the more northern outcrops.

Section of Stones River Limestone South of Bunker Hill.

	Feet.	
Chambersburg Limestone.		
Upper Stones River.		
Lower silica, dove to light-gray limestone.....	185	
Middle Stones River.		
Blue limestone, banded........................	20	
Bluish-gray magnesian, hard limestone.........	35	
Dark-blue weathers to angular blocks, white quartz nodules............................	15	
Bluish to black dolomite weathers grayish-white	37	
Bluish-gray dolomite with breccia at base.....	16	
Gray, brecciated limestone full of irregularly shaped black flints, some 2 by 6 inches in size	4	
Bluish-gray dolomite, lower part white, sandy..	11	
Dark-blue to gray veined limestone with cone-in-cone at bottom and top of ledge............	4	
Bluish-gray, hard dolomite with some iron ore concretions	15	
Bluish-gray dolomite with two feet breccia at base	22	
Dark-gray limestone full of black flints and some pyrite	7	371

Cauliflower chert horizon of Beekmantown (65 feet thick).

The thickness of the Stones River Limestone near the Potomac is 733 feet; near Myers Bridge over the Opequon, 445 feet; south of Martinsburg, 680; and at Bunker Hill, 370 feet.

OUTCROPS.—The outcrops of the Stones River Limestone are usually long, narrow areas near the Martinsburg Shale, and separated from this formation by the narrow outcrops of Chambersburg Limestone. They are usually folded and faulted and do not extend any great distance on the surface. They are with but few exceptions all in Berkeley County.

Only one belt extends across the entire county, and outcrops from the Potomac River north of Millers Bend southwest by Martinsburg, Darkesville, Bunker Hill, and Ridgeway, to the Virginia Line southeast of the last town, a total length of nearly 25 miles. The width of outcrop varies from a few feet to 1,000, with an average width of probably 500. The outcrop is limited on the west by the Beekmantown Limestone, and on the east it is covered by the Chambersburg Limestone. The rocks in this belt usually dip east at high angles. The outcrop is continuous from the north at the river southward beyond Martinsburg. At the south end of the Standard quarries, the formation dips under the Chambersburg; and south of Evans Run, it rises again for a short distance to the surface, then dips and rises again. From east of Tablers Station and one-half mile south, the belt is continuous to the Virginia Line.

This long outcrop is the eastern limb of an anticlinal fold, and the western side of the fold is seen to the north and west of Martinsburg and again to the south of this city. As the formation is traced south, the Lower Stones River group is faulted out, but the Middle and Upper divisions are clearly shown. This belt was the first one of the outcrops to be developed in the quarry industry of the area, and on it are now located some of the largest quarries, as at Millers Bend, Berkeley Station, Martinsburg, and Bunker Hill. A large portion of it has not yet been developed so that the tonnage of low silica limestone still in the ground on this belt is very large. From Martinsburg north to the river, the belt has been too far removed from railroads to open profitable quarries, but the new line of the Williamsport, Nessle and Martinsburg Railroad follows south very close to this outcrop.

South of Martinsburg the outcrop on the western side of the anticlinal fold, locally known as the "west quarry belt", is faulted and the eastern outcrop of this faulted belt unites with the "east quarry belt" on the dipping south end of the fold just north of Evans Run. It is exposed just south of the run in a small area by erosion and removal of the overlying rock in a ravine. Further south the belt comes to the surface and with one short dip, the limestone is continuous southward.

Two miles southeast of Martinsburg on the National Limestone Company tract, another anticlinal fold brings the Stones River to the surface in two belts, one on the east side

PLATE XVIII(A).—Contact of Martinsburg Shales and Marcellus in Railroad Cut North of North Mountain Station.

PLATE XVIII(B).—Bossardville Limestone Ledges on West Slope of Ferrel Ridge.

of the fold, and the other on the west side, with the Beekmantown exposed for some distance in the center of the fold. The west outcrop is of short length, while the east belt has a length of nearly three miles. In this east belt the Upper Stones River pure limestones are well exposed and large quarries opened. The Lower series is absent and the Middle is very thin, so that the cauliflower cherts of the Beekmantown are only a few feet distant from the Upper limestones. The same is true on the east quarry belt at the Standard south quarries.

The southern end of the outcrop of the west belt on the National property is of exceptional purity, running 99 per cent. carbonate of lime in car-load lots. At this pure outcrop the Chambersburg Limestone is faulted out and the Upper Stones River is overlain by Martinsburg Shale. There is also an overturn of the strata at this place and this limestone is underlain by the same shales.

Another outcrop of the Stones River Limestone is found just west of Falling Waters near the crest of a Chambersburg anticline. The curved outcrop is two miles long and 500 feet wide, composed mainly of Upper Stones River very pure limestone. This tract has not yet been developed, but it is now owned by one of the large stone companies of this section. A small outcrop is found southeast of Falling Waters where it is exposed at the surface by erosion in a ravine in the Chambersburg Limestone.

A very interesting and valuable outcrop is located east of Opequon Creek, starting a few miles above the mouth of this stream, and extending south to the main line of the Baltimore and Ohio Railroad. It is a long anticline, four and a half miles from north to south. The two sides of the fold expose the Stones River in two belts which unite at the north and at the south and then disappear, dipping under the Chambersburg, which also in turn disappears beneath the Martinsburg Shale.

Along the center of the fold, the Beekmantown Limestone outcrops. Minor synclinal folds bring the Chambersburg down into the Stones River at the south. The combined width of outcrop of the two belts is about 800 feet.

The Lower division is absent, but both the Middle and Upper Series are well shown. The Upper limestones in these outcrops are very pure, low in silica, and high in carbonate of lime. Large quarries are in operation on this belt near the railroad, while two of the large steel companies and another limestone company own tracts of this land so far undeveloped.

In the southwestern corner of Jefferson County just east of Opequon Creek, an anticlinal fold brings to the surface the Stones River Limestone over a length of two and three-fourths miles. The Lower series is here absent, and the Middle with its black flints is well exposed. The Upper series of pure limestone outcrops with good width.

A long, but discontinuous outcrop of Stones River follows the eastern side of the Chambersburg belt from the mouth of Opequon at the north, southward past Greensburg, Van Clevesville, to near the Van Metre Schoolhouse, a distance of eight miles. It is exposed again at Leetown and extends three miles south. The width of this outcrop is 100 to 250 feet, and it has the appearance of Middle Stones River, with a number of very pure ledges.

Two small, narrow outcrops of this formation are found on the folds to the west of Middleway. A short fold exposes the Upper Stones River Limestone on Whitings Neck in the northeastern corner of Berkeley County, where the limestone is quite pure.

The Stones River Limestone is thus practically confined in outcrop to Berkeley County. The only exceptions are at Leetown, the small outcrops near Middleway, and near the Opequon in the southwestern corner of Jefferson County. Here and there over this latter county, very pure limestones are found and reported as at the same horizon as at Martinsburg. The stone from these belts has a very similar appearance to the Upper Stones River, though they usually run higher in silica, but their stratigraphy places them in the underlying Beekmantown.

This review of the Stones River Limestone outcrops shows that they occur in long narrow belts, and that their total area is small, but the available tonnage of pure limestone of low silica is very large. They represent the most valuable mineral asset in the entire area; and at the present time only a fraction of the available quarry area is utilized. They represent the largest deposits of low silica limestone in this country. The quarry industry of this belt is as yet in its infancy and there is sure to result a great future growth.

CORRELATION.—Fossils are found in a number of the Stones River ledges in the Martinsburg area, but they are so broken that it is difficult to identify them. In the Chambersburg area, Stose collected the following fossils as identified by Ulrich (Jour. of Geol., Vol. XVI, p. 709) which appear to be characteristic of the Chazy of New York:

Stromotocerium sp. nov.
Tetradium "*syringoporoides*"—the single tubed form very characteristic of this formation.
Gyptocystites sp. undet.
Lingulella ? belli (Billings).
Hebertella borealis.
Hebertella vulgaris.
Dinorthis cf. *platys.*
Strophomena aff. S. *charlottae.*
Bucania sulcatina.
Maclurea magna.
Lophospira bicincta.
Isochilina cf. *amiana.*
Ampyx halli.

Near Martinsburg, Stose and Ulrich collected the following from the lower beds:

Solenopora compacta var.
Cyrtodonta sp. nov.
Matheria sp. nov.
Liospira cf. *obtusa.*
Lophospira cf. *perangulata.*
Helicotoma ? sp nov.
Oncoceras ? sp. undet.
Leperditia fabulites.

The fossils and rock characters led Mr. Ulrich to correlate the formation with the Stones River of Tennessee, and this name is used in the present Report.

The Stones River Limestone was named by J. M. Safford in 1856 and he states (Bull. Geol. Soc. Amer., Vol. 13, p. 12) "it was made to include certain bluish, dove-colored limestones, in all about 300 feet thick, and outcropping along the course of the Stones River in Rutherford County, Tennessee, and the lowest (Ordovician) beds to be seen in the central part of the state." He in 1869 substituted the name Lebanon, but the name of Stones River was revived by Winchell and Ulrich and is now in general use. The Stones River of Safford in Tennessee includes the following groups:

Stones River.... { **Lebanon.** **Ridley.** **Pierce.** **Murfreesboro.**

The group is represented in New York in part by the Chazy.

THE BEEKMANTOWN LIMESTONE.

Below the Stones River Formation is a series of magnesian limestones, with beds of quite pure carbonate rock, dolomites, and cherts, which have been correlated with the Beekmantown of Pennsylvania and New York. In the present work of mapping this formation in the eastern Panhandle area, the top of the Beekmantown is taken at the top of the stratum of magnesian limestone containing the cauliflower cherts, thus following the work of Bassler in Maryland.

This cauliflower chert horizon is usually well exposed, and is fairly continuous across the Beekmantown outcrop, and it forms a clear mark for the separation of the Beekmantown from the Stones River. Below this horizon are magnesian limestones usually dark-blue to bluish-gray in color, hard and compact, grading into true dolomites. Associated with these dolomites at certain horizons are large quantities of platy and rounded yellow to white cherts. Along the line of outcrop of these chert horizons, the fields are often a mass of these plates and balls strewn like cobblestones, and very large piles of them are seen here and there in the fields and along fence rows where they have been piled from clearing the land.

One of these chert belts follows a line trending southwest from the Potomac, and passes about half-way between Falling Waters and Spring Mills. By the weathering and solution of the limestones, the cherts are left as residual masses through the soil. They are sometimes in the form of yellow platy blocks, and again they are rounded balls which are quite brittle and white inside covered with a brownish sandy surface. Cryptozoon cherts, possibly of the *Cryptozoon steeli* variety, are also common, and sometimes reach a size of one or two feet diameter. While the cherts appear at various parts of the formation, there are two well-defined horizons, one just above the Stonehenge member, and the other 750 to

800 feet higher. The chert outcrops usually form low ridges across the country.

Through the Beekmantown Formation occur belts of very pure carbonate limestone, quite low in silica, often dove-colored and with smooth fracture, resembling very closely the pure rock of the Upper Stones River. Such belts are often mistaken by the owners and quarrymen for the Stones River, and they are held at high prices for sale as low silica limestone. While they are very good limestones, unfortunately they vary in composition over small distances and have a higher silica average than the Stones River, so that they seldom can stand the rigid tests for open-hearth steel use. A few of these belts are found in Berkeley County and some large belts occur at a number of places in Jefferson County. They should prove valuable for blast-furnace flux, lime, and cement, but it is very doubtful if they would ever find any sale for use at the open-hearth steel plants, until the purer **Stones River Limestones** of the Martinsburg district are exhausted.

The main portion of the Beekmantown consists of dolomites rather high in silica, and magnesian limestones. The basal portion of the formation has a very different appearance from the upper portion, and it has been given the name of Stonehenge by Stose in the Chambersburg area. It consists of siliceous banded and ridged limestones with the ridges usually cross-connected giving a honeycomb effect, and associated with oolites and edgewise conglomerates, thus resembling very much the underlying Conococheague Limestone. It does not contain Cryptozoon, and does carry fossil shells, trilobites, etc. The thickness of this member is 400 to 600 feet, and its outcrop is very distinct but it often requires careful study to separate it from the underlying formation. Usually the platy, buff to brown sandstone near the top of the Conococheague can be followed and thus give a good clue to the line between the two formations. Above the Stonehenge in the northern Berkeley County outcrops, there is a belt of black flints well exposed near Prospect Hill and near the forks of the road one and a half miles west of Falling Waters.

The Beekmantown Formation was first separated from the Shenandoah Limestone group and identified by Stose in Pennsylvania (Mercersburg-Chambersburg Folio). He gives the following composite section of the Beekmantown Limestone as measured by himself and Ulrich near Chambersburg. Pennsylvania:

Beekmantown Section near Chambersburg, Pa. (Ulrich and Stose).

	Feet.	
Interbedded fine-grained pure limestones and magnesian limestones finely laminated in part, and containing small quartz geodes. Porous sandy chert near top	600	
Alternating pure dove and gray limestones and magnesian limestones with layers of sandy chert	375	
Bluish to dove, fine-grained limestone, fossiliferous.	100	
Pink, fine-grained marble, containing layers of milky quartz chert. Gasteropods of genus *Ophileta*, *Maclurea* and *Eccyliopterus* rather abundant	275	
Pure dove and blue, fine-grained limestone with some pink limestones. Contains fragments of *Trilobites*	285	
Fine-grained dove to dark-gray limestone with fine conglomeratic and oolitic beds. Abundant chert in upper portion, in part oolitic and conglomeratic	145	
Fine-grained light- to dark-gray limestone containing contorted laminae of sandy matter, that stand in relief or fall to sandy shale on weathering, and thick beds of "edgewise" conglomerate. Contains Gasteropods in upper portion, and fine fragments of *Trilobites* in lower part. This and the next member form the **Stonehenge Member**.	225	
Dark- to light-gray limestone with sandy laminae less developed than in overlying beds. Contains *Orthis*, *Ophileta*, and *Trilobite* fragments	260	2265

The thickness in West Virginia appears to be around 2,000 feet. The following section was measured west of the Williamsport Pike, one mile west of Berkeley Station, and shows a thickness of 2,110, with the Stonehenge Member 500 feet thick:

Beekmantown Section West of Berkeley Station.

	Feet.	
Bluish-gray limestone with fossils, cauliflower cherts at top	280	
Dark-blue limestone more or less foliated and veined, also shows mottled surfaces	195	
Dark-blue to bluish-gray limestone, irregularly seamed	245	
Dark-blue limestone in solid ledges	250	
Limestone with raised ridges but not siliceous, and some indistinct "edgewise" beds	240	
Foliated and wavy lined limestone, dark-blue	400	
Siliceous banded limestone with oolite and "edgewise", **Stonehenge**	500	2110

North on the Potomac River to the west of the Pittsburgh Limestone Company quarries, the thickness of the Beekmantown is about 2,400 feet, with its Stonehenge Member 465 feet. A section of the upper beds of the formation was measured one mile east of Foltz:

Section of Beekmantown Near Foltz.

	Feet.	
Bluish-gray limestone	105	
Dark-blue limestone	70	
Blocks of loose platy cherts and limestone concealed	60	
Light-gray limestone fairly pure	150	
Blue solid ledges limestone	225	
Dolomite ledges and chert masses	72	
Compact dark-blue limestone weathers light-blue to nearly white	60	
Light-gray, compact dolomite and cherts	64	
Concealed but ground full of chert masses, mostly small	70	
Bluish-gray limestone, striated, white flints	100	
Light-gray limestone, fairly pure carbonate	10	
Light-gray dolomite containing streaks of pure limestone	56	
Dolomite with small white and yellow chert blocks	35	
Light-gray pure dolomite, compact in texture	25	1102

West of Hainesville the thickness appears to be about 2,290 feet, with the Stonehenge Member 500 feet. Northwest of Nipetown, the Stonehenge is 554 feet with a chert horizon above it, and another chert horizon, 375 feet thick, 750 to 800 feet above the Stonehenge. On the road south from the mouth of the Opequon east to Whitings Neck, the following section was measured:

Section of Beekmantown West of Whitings Neck.

		Feet.
Blue limestone full of small cherts, some high-grade ledges		105
Fairly high-grade limestone with some pink to blue marble		210
Blue, compact limestone with cherts and chert gravel		75
Bluish-gray dolomite with cherts and some breccia		45
Blue limestone and small chert balls		200
Blue limestone, shows some veining and mottling on surface		150
Bluish-gray dolomite with pink veined ledges		75
Gray limestone with cherts and some breccia		100
Gray dolomite, fairly high-grade		15
Blue limestone veined and abundant cherts		85
Blue limestone weathers in smooth rounded ledges		170
Flaggy, blue limestone, wavy lined		80
Compact blue limestone, veined with wavy lines		170
Compact blue wavy lined and mottled surfaces	290′	Stonehenge ... 590
Hard blue ridged limestone	115	
Slabby dark-blue limestone	60	
Siliceous banded limestone, breaks flaggy	125	
		2070

OUTCROPS.—The Beekmantown Limestone outcrops cover broad areas in Berkeley and Jefferson Counties. One belt in Berkeley County extends from the Potomac northwest of Falling Waters, southwest by Nipetown, Cumbo, Martinsburg, Inwood, and Bunker Hill, to the State Line, with an average width of one and a half to two miles. Small elongated outcrops occur west to North Mountain in synclinal folds in the Conococheague, as at Prospect Hill, near Spring Mills, Harland Spring, to the south of Hedgesville, and near Gerrardstown.

In the broad belt of Beekmantown, the upper chert horizon is well exposed and makes an almost continuous line of outcrop forming ridges and hills. Along this chert outcrop, the limestone shows only as ledges here and there of bluish-gray bouldery cliffs. The cherts are found at the triangle of the roads one and three-fourths miles northwest of Falling Waters, and from there can be followed south across the fields and on the roads to the railroad east of Cumbo Yard. The cherts continue along this belt to the Virginia Line. They are platy and round, yellow and white blocks, and some of them are balls of Cryptozoon in concentric laminæ. In places blocks of brown hematite iron ore are associated with this horizon, as east of Harland Spring, east of Cumbo and near Cumbo Yard.

In this area another chert horizon occurs in the basal portion of the formation above the Stonehenge, in the form of blocks and balls of black flint. At the top of the Beekmantown is a dark-blue limestone carrying numerous balls of cauliflower yellow cherts.

At the base of the formation is a hard, wavy-bedded and siliceous banded and ridged limestone which closely resembles the underlying Conococheague. It contains breccia of limestone pebbles which are often set oblique to the bedding forming the so-called "edgewise beds", also masses of oolite. In many places these strata are fossiliferous. This portion was named by Stose the Stonehenge Member of the Beekmantown, and in this area it is about 500 feet thick. Its outcrop is found along the Conococheague contact, and by folding it is brought to the surface along various lines within the area. The ridges in the limestone by weathering project a fourth to half inch, and they are very hard and siliceous, usually dark in color and run very irregular with and across the bedding giving a honeycomb structure. The edgewise conglomerate is usually in the form of small, more or less rounded pebbles of limestone, or in other exposures, the pebbles are elongated. The oolite is similar to that in the lower group or Conococheague.

In the main portion of the Beekmantown, the limestones are usually dark-blue to bluish-gray, and more or less banded. In many cases there is a brecciated surface which resembles somewhat the Cryptozoon structure. Again the rock is a brecciated mass of pebbles more or less parallel to the bedding-planes. Magnesian limestones, often almost typical dolomites, are found, but they usually run high in silica.

Most of the limestones of the formation run high in silica and magnesia, but fairly pure limestones are found which in color, structure, and composition are so similar to the pure limestone of the Upper Stones River that they can not be separated in hand specimens. An outcrop of these high-grade ledges along the Potomac near Whitings Neck is remarkable for its resemblance to the high-grade Stones River, but the average composition shows a higher percentage of silica and magnesia. Other belts of this limestone are found along the Potomac west of Millers Bend, where there is a series of gray to white high-grade limestones interbedded with siliceous blue ledges.

A second belt of the Beekmantown Limestone outcrops east of Opequon Creek from the mouth of the Opequon east to Whitings Neck, thence southwest by Van Clevesville, Kearneysville, Leetown, and Summit Point to the Virginia Line. This belt has a width at the north of over two miles, and nearly four miles at the south. Small areas occur to the west of this belt on folds. The Stonehenge Member is well exposed through this outcrop, and the cherts are similar to the western outcrops.

The pure limestone ledges outcrop a half mile west of Scrabble, just west of the church, where there are four belts of the higher-grade limestone separated by belts of the blue more impure rock. These belts vary in thickness from 18 to 185 feet with a total thickness of 365 feet of fairly good rock.

Another belt of this grade limestone over 300 feet wide is seen on the east and west road, three-fourths mile southwest of the Wiltshire Schoolhouse, or about four miles northwest of Charlestown. This belt extends north and south of this road for over a mile in length. A similar belt outcrops a half mile northwest of Kearneysville, and it crosses the Baltimore and Ohio Railroad about a mile west of this town. One and a half miles west of Summit Point is another outcrop of this grade of limestone. Other similar belts will probably be found in this formation. Dolomites in almost typical composition except for high silica are to be found over the Beekmantown areas and should prove valuable for lime. They are found along the Potomac River west of Millers Bend, also to the south and east of Martinsburg, and along the road a mile and a quarter west of Charlestown Careful search would add to this list of localities.

CHAPTER XII.

THE CAMBRIAN PERIOD.

The name Cambrian, derived from the old Latin name for Wales, was given by Sedwick in England in 1835 to include the basal fossil rocks of the Paleozoic System. In the United States it is divided into three groups:

Upper or Saratogan—named from Saratoga Springs.
Middle or Acadian—from an old Canadian name for the Nova Scotia district.
Lower or Georgian—named from the town of Georgia, Vermont.

In the Maryland and West Virginia areas, the following subdivisions are recognized in the Cambrian rocks:

Upper Cambrian or Saratogan—	Conococheague Limestone.
Middle Cambrian or Acadian—	Elbrook Formation. Waynesboro Formation.
Lower Cambrian or Georgian—	Tomstown Limestone. Antietam Sandstone. Harpers Shale. Weverton Sandstone. Loudoun Formation.

CONOCOCHEAGUE LIMESTONE.

Below the Beekmantown Limestone of the Ordovician period is a group of siliceous, more or less magnesian, limestones, characterized by a series of siliceous hard bands which by weathering project, giving a distinct ridged appearance to the outcrop. The limestone was named by Stose in the Mercersburg-Chambersburg Folio, the Conococheague Limestone from its good exposures on the creek of that name. The ridges are usually wavy and contorted and may be a fraction of an inch apart and again two or three inches apart and run to one or two inches thick. They are usually darker in color and more glassy in texture than the limestone and thus are very prominent.

Near the top occur sandstone inclusions and sandstone blocks varying in size up to one and a half feet across, which on weathering of the limestone are left as residual masses over the fields in the form of soft, coarse-grained, buff sandstone blocks more or less tabular and with open spaces from which limestone inclusions have dissolved out.

In a number of places this horizon is marked by continuous ledges of reddish-brown, striated or banded sandstone, which weathers into soft, slabby blocks. Near such outcrops which usually form ridges, the fields are covered with these sandstone blocks, and the soil is sandy. This sandstone is well exposed on the road from dam No. 5 on the Potomac, south for over a mile. Near the river on this road, the limestone contains sandstone inclusions, some of which have weathered out and are scattered along the road and fields west to Prospect Hill.

The top of the Conococheague Formation is placed above this sandstone, while the base is taken at the top of the buff, shaly limestones and cherts of the underlying Elbrook, and below the siliceous banded limestones with their edgewise beds and oolite.

Another characteristic of many of these limestones is a limestone pebble conglomerate, composed of rounded or angular, lighter-colored pebbles in a darker matrix. In other ledges, the included pebbles are elongated, prismatic, set at various angles, forming the "edgewise beds" of Stose. In some blocks there is a solid mass of these edgewise inclusions making a striking and beautiful surface appearance.

Beds of oolite or "eggstone" made up of small rounded concretions of limestone, like a mass of fish eggs, are found throughout the formation. These oolitic structures are now regarded as due to the action of bacteria secreting lime and forming large masses of limestone, which fact may account in part for the great thickness of the Cambrian limestones in this area. While the edgewise conglomerate and oolite are found in the basal portion of the Beekmantown, they are much more abundant and characteristic of the Conococheague.

Associated with the lower beds are irregular, scoriaceous cherts, almost lava- or slag-like in structure. Some of these cherts are composed of pipes filled with white quartz, and more or less open and interlocking, giving a honeycomb appearance. Some of these cherts are three feet in diameter, but they are usually six to ten inches across. In certain localities, as west of Shepherdstown they are very abundant. They are dark-colored almost black, but when broken they are white to brownish-white, and often much iron-stained. While these cherts are found in the basal beds, they also occu through the formation, and large masses are found near the top, to the south of Shenandoah Junction.

Another characteristic structure of the Conococheague Limestones is the Cryptozoon which has a concretionary structure, but is regarded by most authorities as a fossil. It has a concentric, laminated structure in round or oblong masses, single or double, and varying in size from less than an inch to several feet in diameter. By weathering, the agate-like bandings of this fossil are clearly shown, and the forms are very abundant at many localities. Beautiful specimens are found in the vicinity of Little Georgetown; also in the Baltimore and Ohio Railroad cuts three-fourths mile south of North Mountain Station, where the Cryptozoon is associated with edgewise beds; also in the cut across the end of North Mountain on the low-grade railroad along the Potomac. In the railroad and county-road cuts of this area some of the Cryptozoon forms are very large. Good specimens are seen northwest of Shepherdstown, and in the Conococheague outcrop west from Bunker Hill. Probably the most characteristic form is the *Cryptozoon proliferum* in which the fossil is a mass of rounded or angular, small sections crowded together.

While many of the limestones of this formation are characterized by the siliceous banding, there are also ledges of marble, pure carbonate limestone, and shaly, flaggy layers. In the lower part of the formation is a stratum of very pure limestone which can be traced through the Jefferson County outcrop. West of Spring Mills toward North Mountain is a very shaly limestone series that resembles the Elbrook Formation, and which is illustrated by the following section which could be almost duplicated at a number of other places in the two counties.

Section of Shaly Limestone Beds in Conococheague.

	Feet.	
Solid ledge grayish-black limestone	3	
Shaly gray limestone, weathers buff	22	
Solid ledge limestone, cross-jointed	5	
Shaly bluish-gray limestone	14	
Solid limestone, foliated	3	
Shaly limestone weathers to shales	40	
Solid ledge limestone but breaks shaly	4	
Flaggy bluish-gray limestone	12	
Flaggy limestone with honeycomb structure	5	
Shaly limestone	26	
Solid ledge sandy limestone	8	
Shaly limestone	7	
Strongly foliated limestone breaks nodular	36	
Shaly limestone	16	
Solid ledge limestone	3	
Shaly limestone and shales	55	
Solid grayish-black limestone	7	
Solid limestone breaks into plates	5	
Solid limestone, foliated	18	
Solid grayish-blue limestone	3	
Foliated and shaly limestone	5	
Solid limestone	12	
Shaly limestone	5	
Solid limestone, strongly foliated	12	326

Shaly limestone in the valley.

The middle and upper portions of the formation form solid ledges of bluish-gray to nearly black limestone which still show the contorted lamination and ridged surfaces, and there are also outcrops of gray to bluish-gray and buff dolomites.

The ledges of marble are found at several places in the lower part of the formation. They are light-gray to buff in color with a pink tinge, and break in compact blocks with smooth surfaces. They were seen in the eastern outcrop in Jefferson County east of Shepherdstown and other places. At the river just east of this town on the county road there is an outcrop of marble conglomerate with elongated pink angular inclusions in a glassy white matrix. Vein-quartz nuggets occur through the lower portion of the formation, but these are not abundant.

The thickness of the formation in the Chambersburg Pennsylvania, area, according to Stose, is about 1,600 feet. In the northern portion of Berkeley County near the Potomac, the thickness is about 1,800 feet, and 1,600 to 1,800 in several sections in Jefferson County.

In this area no complete sections were made, but the following partial sections show the character of the basal and top portions. The first section was made in the cut along the low-grade line of the Baltimore and Ohio Railroad, one mile southeast of North Mountain Station. It shows 555 feet of the basal beds:

Section of the Basal Beds of Conococheague, West of Cumbo.

	Feet.	
Dark-blue limestone some shaly layers, full of *Cryptozoon*, oolites, edgewise beds	25	
Wavy crumpled banded ledges with *Cryptozoon*	15	
Bluish-gray with some shaly ledges, *Cryptozoon proliferum*	40	
Solid ridged ledges limestone	10	
Shales and shaly limestone	10	
Solid ledges irregularly seamed	22	
Strongly siliceous banded limestone, and shales	41	
Bluish-gray shaly limestone	54	
Slabby or flaggy ledges 8 inches to 1 foot thick	45	
Solid blue limestone, with *Cryptozoon*	34	
Buff shaly limestone	10	
Bluish-gray limestone with large sized *Cryptozoon*	30	
Buff shaly limestone and shales	27	
Solid ledges with *Cryptozoon proliferum* and oolite	59	
Bluish-gray dolomite with *Cryptozoon proliferum*	30	
Buff shaly limestone	18	
Solid ledges some oolite, and some quite pure limestone ledges	36	
Flaggy buff limestone	8	
Blocky, buff limestone showing worm trails	7	
Shaly ledges of limestone	22	
Bluish-gray limestone with *Cryptozoon proliferum*	12	555

Elbrook buff shaly limestone.

Another section of the top beds was made west of the Norfolk and Western Railroad on the North Fork of Bullskin Run, three miles southwest of Charlestown:

PLATE XIX.—Detailed Structure in White Medina Sandstone Cliff at Eades Fort. (Photo from Pawpaw-Hancock Folio of U. S. Geological Survey).

stone. The edgewise beds are also well shown, and some ledges show ripple-marks and sun-cracked surfaces.

The limestones of this formation are usually dark-blue to black in color, with ledges of bluish-gray. They are usually hard and solid; but flaggy, shaly ledges occur which weather to shales. The siliceous banding is very characteristic, as well as Cryptozoon, oolitic, and edgewise conglomeratic structures. Near the Potomac, and to the east and south of North Mountain Station, some very large balls of Cryptozoon are seen, reaching two to three feet in diameter. Scoriaceous, dark-colored cherts and nuggets of white vein-quartz occur here and there, especially in the lower part of the formation. Ledges of very pure gray limestone are also found, which are similar to those in the Beekmantown.

The base of the formation is placed just above the shaly buff limestones of the Elbrook. A sandstone outcrop is found near this horizon at a few places, but it does not appear to be continuous. It is well exposed just northwest of Arden. A small outcrop of Conococheague Limestone with *Cryptozoon proliferum*, oolite, and "edgewise" beds, is found in a synclinal area near the south line of the county east of North Mountain, and east of Mill Creek, and it extends north to Gerrardstown.

The Conococheague Limestones are found again in the eastern portion of Jefferson County extending in an unbroken belt from the north line of the county from Scrabble east across Terrapin Neck, thence southwest across the entire county. The length of this outcrop is 21 miles, with a width of three miles at the north, and about a half mile at the Virginia Line. Its boundaries are more regular than in Berkeley County, and it does not seem to be broken by folds deep enough to bring the Beekmantown through it to the surface.

In the northwestern portion of the area are the siliceous banded and ridged limestones, and scoriaceous cherts which reach a large size. On Terrapin Neck, on the Martinsburg Pike, one mile west of Shepherdstown, and one mile south of this town, and west of the Shepherd Schoolhouse, these cherts are two to three feet in diameter. Many of them are composed of pipes with the quartz filling, and they have been gathered from the fields into large piles. Fine specimens of *Cryptozoon proliferum* are found two to three miles northwest of Shepherdstown, also typical exposures of oolite and "edgewise" beds. To the west of this town is an outcrop of purplish-gray, granular, high-grade limestone, with some ledges wavy-lined breaking in slabby courses. Other ledges are seamed by calcite masses reaching one and a half feet long and eight inches wide, running at right angles to the bedding-planes. To the east of town are ledges of the marble, some of which are a breccia. Three miles south are ledges of very pure limestone resembling in appearance the Stones River pure beds. This horizon is in the lower portion of the Conococheague, and the stratum is found at a number of places further south.

Two miles north of Shenandoah Junction, the platy, reddish-brown, striated sandstone outcrops in the road for a distance of three-fourths mile, and it is there taken as the top of the formation. Further north the sandstone outcrop is not clearly exposed, except along the north road just east of Scrabble.

Three-fourths mile north of Shenandoah Junction is an outcrop of the light-gray marble. To the south of town are siliceous banded limestones, "edgewise" beds, and the typical scoriaceous cherts. No clear specimens of Cryptozoon were found here, but at a number of places the rock shows concentric, wavy markings which resemble Cryptozoon. The sandstone stratum at the top of the formation is well exposed from northwest of Charlestown south to the Virginia Line.

The outcrops of the Conococheague become narrow from Charlestown south to the Virginia Line. The "edgewise" beds are seen west of Rippon, but *Cryptozoon* appears to be absent. The thickness of the formation in the southern part of the county east of Franklintown is 1,800 feet. **The Conococheague Limestones** are quarried at a number of places on a small scale for road material, as west of Charlestown, southwest of Shepherdstown, and along the various roads on its outcrop in Jefferson County. No large quarries have ever been opened. The hard siliceous beds are regarded very highly for road material, and this county has the best roads in the State.

CORRELATION.—No fossils are found in this formation in the two counties except the Cryptozoon forms. In the Chambersburg, Pennsylvania, area, Stose collected from the middle of the formation a few trilobites (*Dikeleocephalus hartii*, Walcott), and an undetermined species of this same genus, which placed the horizon in the Saratogan or Upper Cambrian. The *Cryptozoon proliferum* of the lower portion of the formation was described by Hall and also by Walcott from near the top of the Upper Cambrian of New York. The formation is therefore regarded as Upper Cambrian. Stose states in the Chambersburg Folio that the Knox Dolomite of Tennessee includes strata equivalent to both the Beekmantown and the Conococheague.

ELBROOK FORMATION.

Below the Conococheague Limestone is a series of shaly limestones, and limy shales, with ledges of more solid blue to blue-gray limestones, which were named by Stose, the Elbrook Formation, from a town in the Chambersburg Quadrangle, where the more solid ledges were quarried for ballast.

In the eastern Panhandle area of West Virginia, this formation is typically exposed in two outcrops, one in Berkeley County, and one in Jefferson. The rocks are mainly buff, shaly limestones which soon break down into platy shales. As these outcrops are usually much weathered, their color is light- to creamy-buff, with very smooth surfaces and quite uniform texture. The shales vary from platy blocks to fine flaky leaves, and they are found throughout the formation. In unweathered exposures, the color of the limestone is blue, but the solid ledges soon weather to shales and sections of the formation are difficult to obtain.

Through the Elbrook are harder, more compact ledges of blue limestone, sometimes ridged like the overlying formation. The blue ledges are usually very finely striated or banded, giving an agate-like appearance, and the rock splits along these planes. Near the center of the Elbrook Formation are massive ledges of bluish-gray dolomite which becomes a good quarry and road material stone. This dolomite is often ridged, but shows no "edgewise" or oolitic structures.

Cherts are very abundant in the Elbrook and the fields are dotted with chert piles like in portions of the Beekmantown outcrops. They form long rows along the fences where gathered from the fields. They are hard, white, yellow, and gray balls, seldom with any concentric structure. Some are brecciated masses of angular chert fragments, and a few flat, platy cherts are found. The characteristic appearance of the typical cherts is a waxy or dull lustre like chalcedony, and they are chalcedonic cherts. Some blocks of drusy quartz occur. Blocks of bright-yellow cherts with glistening quartz faces are also characteristic of the formation. The chert balls are usually six to ten inches in diameter, though a few are two feet across. Along certain roads, as the north-and-south road south of Hedgesville and a mile west of Welltown Schoolhouse, the cherts are very abundant, and they are used for road material.

The Elbrook shaly belt with its associated cherts near North Mountain is a great orchard belt, and the outcrop can almost be traced by the line of orchards. The chert or flint lands are claimed to be especially favorable for apples giving a good flavor and production, with a good drainage and air circulation soil. This belt includes the "apple-pie ridge" orchards and those near Gerrardstown. In the Jefferson County Elbrook area, there are a number of orchards, but it has not been followed so closely as in Berkeley.

OUTCROPS.—A long, narrow belt of Elbrook outcrops in Berkeley County to the east of North Mountain extending from the Potomac River near McCoys Ferry, southwest into Frederick County, Virginia. Its length in Berkeley County is 22½ miles with an average width of a half to three-fourths mile.

Along the Potomac in the cuts of the railroad the formation is an anticlinal fold with the eastern limb about 660 feet thick, and the western side about 500 feet, and it is faulted against the Medina White Sandstone. A section of the east side of the fold shows the following strata:

Section of Elbrook on Potomac River.

	Feet.	
Conococheague Limestone.		
Buff limestone with calcite streaks.................	20	
Concealed in deep ravine........................	300	
Shaly buff limestone in fairly solid ledges.........	22	
Shaly limestone with some blue solid ledges......	150	
Flaggy ledges, buff limestone, blue unweathered....	35	
Blue limestone breaks in irregular blocks.........	15	
Darker bluish-gray limestone, more solid courses...	16	
Agate-lined or veined limestone....................	15	
Shaly limestone weathers to shales................	55	
Flaggy limestone weathers cobbly on surface.......	12	
Brecciated limestone (inclusions 1 to 2 inches).....	6	
Solid ledges of foliated limestone..................	10	656

As the formation is traced southward from the Potomac, it shows shales and shaly limestones, with the platy shales more prominent as results of weathering. The formation is well exposed just east of North Mountain Station and in the railroad cuts just south. A mile south of this place, small synclinal folds bring the Conococheague to the surface and the boundary is quite broken. The chert horizon is now exposed, and these cherts become characteristic of the formation on south, and the Elbrook outcrop is also wider than at the north.

Two and a fourth miles southeast of Hedgesville and west of the Welltown Schoolhouse, the structure is still anticlinal with east and west dips around 50 to 60 degrees. A section on the eastern side of the fold shows the following strata:

Section of Elbrook South of Hedgesville.

	Feet.	
Buff, flaggy limestone...........................	80	
Bluish-gray limestone weathers to platy shales.....	10	
Shaly limestone and shales.........................	55	
Blue limestone in solid ledges.....................	40	
Concealed and shales............................	150	
Soft, buff, flaky shales...........................	10	
Shaly, buff limestone, some angular blocks.........	78	
Blue, hard limestone, agate-banded.................	6	
Shaly, buff limestone.............................	40	
Blue limestone, hard, and in solid ledges............	20	489

Further west, the chert horizon appears to be about 300 feet above the top of this partial section. On the western side of the fold, a thickness of 1,400 feet was measured, and the measures were then obscured by weathering and folding, so that the actual thickness of the Elbrook could not be determined in this portion of the area. In the railroad cut a mile east of Hedgesville, the more massive dolomite ledges of the middle portion of the formation are exposed.

Further south, to the west of Nollville, the thickness of the Elbrook is about 2,200 feet, and the middle dolomite ledges outcrop about a mile west of this settlement, while along the ridge and the road to the north, is a well-marked chert horizon below the dolomite. The cherts have been crushed for road material in this area, but the rock does not cement or pack very solid, making a loose, rough road-bed, but which is quite durable. To the north of this west road from Nollville and for miles south are large orchards which have been planted on the chert ridge. In places the ground is one mass of cherts with little loose soil visible, and such tracts are regarded as ideal orchard lands.

On the ridge to the northwest of Arden, and to the southwest, the Elbrook is composed of the platy limestone and limy shales, and cherts. Here also are found outcrops of a yellow, very soft sandstone, of light weight, resembling a Tripoli or scouring-powder rock. There are a number of outcrops of this material in this area and also further south. The sandstone of this character is also found in the next lower formation, the Waynesboro.

In the area east of Gerrardstown, the Elbrook is similar to the area north and large orchards in this section are located on its outcrop. In the southern part of the county near Ridge Schoolhouse, the western slope of the ridge is covered with cherts, some of which are three feet in diameter. On the ridge near the schoolhouse are outcrops of the shales and shaly limestone but no cherts. Here also are ledges of the soft, low-gravity, yellow Tripoli sandstone. On the eastern side of the ridge, the cherts are less abundant than on the west slope. The thickness of the Elbrook at this place is approximately 2,400 feet.

The other outcrop of the Elbrook is in the eastern part of Jefferson County, and it is much larger than the outcrop in Berkeley. It is nearly twenty miles long from the Potomac River a mile east of Shepherdstown southwest across the county, with an average width of nearly two miles.

As in Berkeley County, the formation includes buff shales, shaly or platy limestones, with ledges of blue limestone more or less finely striated or agate-banded, and the cherts. The platy limestones soon weather to shales, so that surface outcrops are very shaly, and good sections of the formation are rare. The cherts are still characteristic of the formation and show similar characters to those described in Berkeley County. The chalcedony cherts and the yellow, sparkling flints are common, and vein-quartz is also found, but only in small quantity and at a few localities. The Elbrook in this area is much folded and faulted.

At the north along the Potomac east of Shepherdstown near the old cement quarries, the Elbrook forms vertical cliffs, 100 to 140 feet high, with the rock ledges nearly vertical. The limestone at this place is all more or less magnesian, and some strata are dolomites. Certain ledges burn into a natural cement, and these were quarried and burned for many years at the old mill located near the cliffs. These old quarries were worked back into the cliffs, leaving the unsuitable rock between as wide ribs in the quarry. With the rapid growth of the Portland cement industry, the demand for natural cement decreased and this mill was abandoned a number of years ago.

In these river cement cliffs, the limestone is foliated, often wavy-banded, and more or less folded. The fine striation or agate-banding is well shown in many ledges. Marble strata are also found. The usual color is dark-blue to bluish-gray, but some ledges are light-gray or almost white, and weather to angular blocks. The flaky, limy shales are seldom seen in the river cliffs and the outcrops are quite solid and have a fresh appearance.

Along the county road from Shepherdstown east to the river, the cuts show the typical Conococheague Limestone, separated from the Elbrook on the east by a deep ravine, and probably also by a fault at this place. As the road bends east along the river bank, the high south wall is formed by the Elbrook cliffs. Near the old cement mill is found the Elbrook-Waynesboro contact in a high smooth wall of Waynesboro Limestone seamed with quartz.

While the Elbrook in this area along the river shows much minor folding, its outcrop is really a syncline with an anticline near the mill, and east of the mill there is a series of short anticlines and synclines, well shown in the river cliffs on the Maryland side. The following section was measured along the western side of the syncline, but on account of the faulting at the west end, and folding at the east end, it is only a partial section of the Elbrook Formation. The chert horizon does not appear in the river section:

Partial Section of Elbrook at Potomac River East of Shepherdstown.

	Feet.	
Conococheague Limestone.		
Concealed in ravine	45	
Wavy-lined, crumpled limestone	15	
Shaly limestone which weathers to shales	3	
Blue limestone foliated and tends to break flaggy	20	
Bluish-gray limestone, magnesian, weathers flaggy	32	
Bluish-gray somewhat flaggy limestone (old cement quarry)	16	
Dark-blue limestone, flaggy, some pink-tinged ledges	55	
Flaggy blue limestone	57	
Solid ledges but weather flaggy or slabby	50	
Limestone with pink tinge, breaks to thin plates	16	
Concealed in an old caved opening	25	
Solid ledges, with pink tinge, breaks to angular blocks	30	
Light-gray, magnesian limestone, solid ledge	6	
Concealed, but the rock weathers in slabs	25	
Dark-blue limestone in solid ledge	8	
Concealed	50	
Finely striated blue limestone, weathers flaggy	54	
Concealed, but here and there angular, slabby blocks	60	
Solid ledges of magnesian limestone in block ledges	80	
Shaly limestone	25	
Light-gray magnesian limestone in blocky ledges	25	
Concealed in ravine to the deep cement quarry	70	
Flaggy gray limestone, some blocky (old cement quarry)	50	
Bluish-gray limestone, wavy-lined, blocky ledges	70	
Shaly and blocky, blue limestone	65	
Light-gray limestone in solid ledges	15	
Limestone in high cliffs and blocky ledges	60	
Magnesian, bluish-gray limestone (old cement quarry)	20	1047

This section can not be carried further east with any degree of accuracy, on account of the folding. There are six of the old cement quarries east of this section, which supplied rock to the mill. The rock is flaggy and in places it is seamed with calcite, and in the larger quarry shows ripple-marked surfaces. Some of the ledges have a greenish-gray color, and nearly all the rock is high in magnesia.

Following across this section on the east-and-west road, a mile south of these cliffs, the weathered outcrop shows a series of platy shales and shaly limetone with but a few solid ledges, and so presents a very different appearance to the less weathered outcrops in these river cliffs.

Further east on this same road are found the brecciated and chalcedony cherts; and the solid, blue, magnesian ledges outcrop less than a mile west of Moler Crossroads. The formation on this road is in a syncline with the center of the fold to the west of Rattlesnake Run. The eastern side of the fold has an approximate thickness of 1,500 feet; and the western limb has a measured thickness of 3,700 feet, but it is much broken by minor folding so that the actual thickness can again only be approximated, but it is probably around 2,500 feet.

Further south near Uvilla, the formation is very shaly, and here again the cherts are very numerous, some white and botryoidal, others dark-colored and more or less sandy. Here also are found the blocks of bright-yellow, sparkling flints nearly two feet square, also blocks of the light-weight, yellow, Tripoli sandstone. Northwest of Reedson is a very long outcrop of the solid magnesian ledges with projecting ridges thus resembling the Conococheague Formation, and representing the middle portion of the Elbrook. Marble ledges also occur, and the apparent thickness of the Elbrook in this area is about 3,000 feet, but there may be an error in this measurement due to folding.

A partial section of the Elbrook three-fourths mile north of Reedson and north of the Baltimore and Ohio Railroad shows the relation of the soft Tripoli sandstone to the limestone in the lower part of the formation:

Partial Section of Elbrook East of Duffields.

	Feet.	
Shaly, buff limestone and shales..................	50	
Yellow, soft, Tripoli sandstone....................	3	
Blue, striated, hard limestone with Tripoli.........	8	
Yellow, soft Tripoli sandstone.....................	2	
Blue, striated limestone...........................	7	
Shaly, buff limestone and limy shales...............	50	
Shales and concealed..............................	80	
Blocky and platy, limy shales, and blocks of Tripoli..	25	
Shales, limy, and some blocks of white vein-quartz...	25	
Shaly limestone and chert blocks (1 to 2 feet, diameter	30	
Shales and concealed, some quartz blocks..........	140	
Bluish-gray, agate-lined limestone.................	5	
Shales and concealed.............................	100	
Platy, buff shales................................	15	540
Bluish-white marble of Waynesboro................		

On the east-and-west road two miles south of the Baltimore and Ohio Railroad at Duffields, the Elbrook outcrop forms a synclinal fold with its center one and a fourth miles southwest of Reedson, just east of the long bend of this road to the northeast (U. S. 448 feet). The thickness on the eastern side of the fold, is 1,200 feet; and on the west it is approximately 2,500 feet. The formation consists of shales and shaly buff limestones, with one small ledge of marble near the center of the fold. The cherts are found throughout the area scattered over the ground.

On the next road south, the shales and shaly limestone are seen, but with very poor outcrops. The city of Charlestown is built on Elbrook, and the street and cellar excavations show the ledges of buff, shaly limestone, and in places the solid, blue limestone. A number of folds at this place bring to the surface the underlying Waynesboro marbles and sericitic shales. The railroad cuts near this place show good outcrops of Elbrook. The brick-yards north of town use a red clay overlying the Elbrook Limestone, and in the pits the projecting ledges of finely striated, dark-blue, and bluish-gray limestone are exposed.

Southeast of Charlestown on the road leading northeast from Mechanicstown, are good outcrops of the shaly limestone and cherts. The agate-lined limestone, large and small chert balls, and yellow, sparkling flints, are very prominent in the vicinity of Cattail Run on this road. Some of the chert balls reach a diameter of two feet.

Two and a fourth miles south of Charlestown on the cross-road north of the North Fork of Bullskin Run and east of the Norfolk and Western Railroad, the contact between the Conococheague and Elbrook is very sharp in a road-cut near the top of the ridge, and the following section was measured here on the western side of a small anticline:

Partial Section of Elbrook South of Charlestown.

	Feet.	
Conococheague Limestone.		
Shaly, blue limestone	3	
Solid, blue limestone	2	
Buff, platy sandstone, soft	6	
Sandy shales	22	
Shaly limestone and limy shales	8	
Agate-lined dark-blue limestone	5	
Shales and shaly limestone with a two-foot solid ledge	37	
Solid blue limestone	5	
Shales, more or less limy	60	
Solid, bluish-gray limestone	15	
Shaly blue limestone	3	
Gray, hard limestone, almost a marble	8	
Blue limestone, somewhat brecciated	7	
Buff limestone, breaks in shaly blocks	8	
Dark-blue limestone	5	
Shales and concealed in the valley	165	
Platy shales, some ledges of blue limestone	120	479

This section is of the upper part of the formation, and the lower part of the Elbrook is here obscured by numerous small folds. Further east in these folds, the shaly limestone and limy shales continue, also ledges of the soft, yellow Tripoli sandstone. Similar deposits of this sandstone are found to the east of the Berryville road, where in 24 feet of shaly limestone, six to eight feet of the Tripoli sandstones are interbedded.

In the southern part of the county near Rippon and to the north, south, and east, the cherts are very abundant. The formation here is composed of the buff shales, shaly limestone, with ledges of solid, blue, striated limestone. Some of the ledges are very dark-blue, almost black. No good complete sections were found in this area, and it was impossible to measure the thickness with any degree of acuracy. The thickness of the Elbrook in the eastern part of Jefferson County is probably 2,500 to 3,000 feet.

Fossils were not found in the Elbrook in Berkeley or Jefferson Counties. Stose found some fragments of trilobites in the basal beds in Pennsylvania, and he regards the age as probably Middle Cambrian.

THE WAYNESBORO FORMATION.

Below the Elbrook shaly limestone series, is a mass of more or less siliceous or sandy beds, with dolomites and marble, named by Stose (Mercersburg-Chambersburg Folio, No. 170), the Waynesboro Formation from its typical development near the town of that name in Pennsylvania. In Pennsylvania, Stose states that the top of the formation is marked by mottled, slabby sandstone and dark siliceous purple shale; while at the bottom are found "very siliceous limestones that weather to slabby, porous sandstone, large masses of rugose chert, and white vein-quartz."

In West Virginia where the Waynesboro forms a broad outcrop in the eastern portion of Jefferson County, the purple siliceous shale is readily identified, but above it there is found a series of sandy shales, dolomite, and siliceous, blue limestone.

At the base of the formation in this area at the north near the Potomac, is a finely laminated, blue, siliceous limestone, carrying blocks of rugose quartz and masses of white vein-quartz. Some of the limestone ledges carry platy inclusions of gray sandstone reaching a length of thirty inches and about an inch thick. Over a considerable portion of the area, the base of the formation is a dark-blue limestone with crumpled foliations, and which is quite siliceous and hard.

A little higher in these basal beds are ledges of blue and cream-buff marble and blocks of white flint. The Waynesboro in this area is separated from the Elbrook by a fault so that the real basal beds may not be represented in all the sections. At this horizon in a few outcrops occur buff sandstone ledges, very soft, which weather into blocks or slabs, and they are associated with sandy shales and blocks of quartz. Some of the lower blue limestones are wavy-lined with crystal calcite along the folia which gives a ridged appearance to the outcropping ledge, and the rock breaks into slabs coated with the glistening calcite.

In the lower portion of the Waynesboro Formation are beds of marble, often snow-white and semi-crystalline. In other ledges, the marble has a vitreous or glassy surface, and it is then compact and hard, though quite brittle. There are ledges of bluish-gray and pink marble which are banded by darker streaks and break in slabs along these planes.

Near the folds, the marble is quite crystalline and is broken into laminæ a half inch thick, forming a very flaggy or shaly outcrop. These laminated marbles are found at many places, but they are well shown in the railroad cuts just east of Engle Station. The marble ledges are three to eight feet thick, and they are often covered by thin courses of slabby, buff limestone, coated with sericite, or in some exposures have chloritic shaly leaves. These sericitic, shaly ledges are found in many outcrops over the area, and are locally called soapstones on account of the smooth, greasy surface.

Near the middle of the Waynesboro Formation are massive beds of blue limestone and dolomite which are quarried in Jefferson County at Bakerton and Engle, and further south at Millville. These limestones could be quarried at a number of other localities in this area.

The ballast quarries one mile west of Engle Station are probably below the middle beds. The quarries were opened on an anticline with a dip to the east and west of 40 to 45 degrees. The limestone is blue and hard, separated from a lighter-colored limestone to the west by a broad belt of the sericitic shaly limestone. Some of the lighter-gray ledges are very pure limestone as shown by the following Survey analyses:

Engle Quarry.	Blue Limestone.	Gray Limestone.
Lime carbonate........	92.27	98.21
Magnesium carbonate..	3.18	0.86
Silica	1.18	0.02
Iron and alumina......	1.60	0.75
Sulphur	0.51	0.09
Phosphorus	0.08	0.007
	98.82	99.937

To the north of the station at Engle is an old lime quarry in a synclinal fold about the middle of the Waynesboro, and probably below the purple shale horizon which outcrops to the west and northwest of the quarry. In the basal beds of the quarry are bands of black flint. The old **Keller lime quarry** east of Engle Station and south of the railroad tracks shows 6 to 15 feet of red clay cover, then 10 feet of blue limestone with irregular fracture weathered at the top into rounded boulders. The basal portion of the quarry, about 20 feet thick, is a blue, somewhat granular limestone which for many years was burned into lime. This is apparently the same horizon as the Bakerton quarry, two miles north, and is in the middle of the Waynesboro.

The **Bakerton quarry** is located on the almost flat portion of a small anticline with the rock dipping a few degrees west. The lower twelve feet of the quarry face is seamed with calcite and is not used for lime. The next ledge above, 12 to 15 feet, is dark-blue and is used with the next ten feet of gray limestone. Near the top is a five-foot ledge of hard, blue limestone with a sandy texture that is discarded.

On the continuation of the line of the Bakerton and Keller quarries three miles south of the railroad is the **Blair quarry** where the rock is a dark-blue dolomite of low silica, and the same belt outcrops for two miles further south as a good quarry stone. Further east at Millville is a long, narrow belt of this dolomite that extends from the Baltimore and Ohio Railroad west of Harpers Ferry a mile and a half, thence south to Millville and across the river. The dolomite is of theoretical composition and very low in silica. Large quarries are in operation on this belt at Millville and the stone is shipped mainly to Pittsburgh steel furnaces.

The upper portion of the Waynesboro consists of sandy shale, buff sandstones, purple shales, sandstone, and blue limestones, which are usually very hard and siliceous. The shales are often ripple-marked and show well-defined sun-cracks, thus representing an abrupt change to more shallow water conditions from the deeper water of the middle division where the more massive limestones and dolomites were deposited. These sandy shales, ripple-marked and sun-cracked, are exposed to the east of Moler Crossroads, also in the railroad cut about midway between Engle and Harpers Ferry, south near Mechanicstown, and at a number of other localities. They grade upward into the shaly sandstone strata. The sandstones often have a purplish cast, and while in some outcrops they are hard and resistant to weathering action, they are more often soft, blocky or flaggy, and sometimes banded almost agate-like. The ledges are one to four feet thick, and grade into shales.

Through the upper part of the Waynesboro, as in the Elbrook, occur ledges of the soft, yellow, Tripoli sandstone, very light in weight. The grit is fine, and blocks, apparently solid, readily crumble in the fingers, so that the material probably could be washed and used as a polishing agent. There appears to be no regularity in the occurrence of the ledges of this material, though it is more often associated with the limestone than with the shales. It often occurs as a distinct ledge two to four feet thick interbedded with blue limestones, and again it is found interbedded with sandy shales.

Marble ledges are found in the upper part of the formation, but they appear to be more common in the lower portion of the Waynesboro. There is one horizon of very white marble in the upper Waynesboro that is about five feet thick, overlain by a hard deep-blue limestone, and underlain by a hard, blue siliceous limestone. This association of marble and blue limestones is seen near Charlestown to the north and south of that town where the Waynesboro is brought to the surface through the Elbrook by anticlines. The same association is seen east of Harmony on a similar anticline, and just west of Kabletown.

Black cherts are found in the blue limestone near the middle of the series at Engle, and along the road to the north

PLATE XX(A).—Conococheague Limestone with Sandstone Inclusions on Road to C. & O. Canal Dam No. 5.

PLATE XX(B).—White Medina Sandstone on North Mountain near North End, Showing Jointing-and Bedding-Planes.

where they have weathered out of the limestone, and they are here very abundant. They are also seen on the pike south of Meyerstown.

White vein-quartz is very characteristic of the Waynesboro in this area. It forms distinct layers in the limestone six to ten inches thick. On weathering, the quartz blocks remain in the soil, and are scattered over the fields or gathered and piled along fence rows. They vary in size from a fraction of an inch to nearly three feet across, and are usually compact and solid, though in some places they are drusy and full of cavities. They are found at various horizons, but appear to be more abundant in the basal portion. While this white vein-quartz is found to some extent in the Elbrook, and at a few places in the Conococheague, it is especially characteristic of the Waynesboro Formation.

The purple shaly sandstone or shales, in places with a purple-bronze cast, forms a well-defined belt that extends from the northeastern corner of Jefferson County, to the northeast of Moler Crossroads, southwest past Engle, just east of Halltown and Mechanicstown. Its outcrop is seen on nearly every road in that direction, and by weathering it forms a purple soil in the fields. This purple shale is usually ripple-marked, and it breaks into thin sandy laminæ. In the Pennsylvania sections, it is taken as marking the top of the Waynesboro, but in the Jefferson County Area, there are shaly buff sandstones and shales above; also in some sections, buff dolomites, and hard, blue, siliceous limestones.

To illustrate the character of the rocks in the Waynesboro Formation of the eastern part of Jefferson County, the following sections are given. The first one was measured along the county road leading northwest from Moler Crossroads to the river, the top of the section being at the river:

Waynesboro Section Northeast of Moler Crossroads.

	Feet.
Blue limestone, very hard, finely striated, streaks of quartz	40
Shelly, blue limestone, sandy, weathers shaly	12
Concealed, some limestone ledges exposed	168

	Feet.	
Blue limestone, mottled, purplish tinge, calcite, used for lime	50	
Blue limestone, and partly concealed	120	
Blue-gray to cream-colored, striated, limestone	15	
Concealed	42	
Soft, yellow, light-weight Tripoli sandstone	6	
Cream-buff dolomite	8	
Soft, yellow Tripoli sandstone	20	
Purple-bronze platy sandstone	14	
Flaggy, brown sandstone, striated	15	
Purple, shaly sandstone	12	
Shales and concealed	42	
Flaggy brown sandstone with hard red sandstone streaks, 1 to 4 inches wide, ripple-marked	8	
Bluish-gray siliceous limestone with crumpled folia	15	
Calcareous shales	30	
Bluish-gray limestone weathers flaggy	8	
Shaly sandstone and sandy shales	31	
Yellow, blocky, soft sandstone	22	
Siliceous limestone	4	
Red to buff, soft, flag sandstone and shales	27	
Cream-buff dolomite, fine-grained, with white quartz seams	15	
Buff, calcareous sandstone	36	
Greenish shaly sandstone, plates hard	15	
Purple shaly but hard sandstone	10	
Sandstone with blue limestone bands, 2 to 3 inches thick	15	
Shaly gray and buff sandstone	13	
Gray siliceous flaggy limestone	15	
Sandy blocky shales with streak red sandstone at base	27	
Flaggy gray sandstone and shales, some quartz	58	
Soft, yellow Tripoli sandstone, in ledges	10	
Concealed	35	
Sericitic platy limestone	6	
Buff sandy shales and blocky sandstone	110	
Sandy shales with ledges red, striated, light-weight sandstone	183	
Soft, red, light-weight sandstone with sparkling surfaces	30	
Concealed	150	
Flaggy, buff limestone, crumpled in small folds	25	
Concealed	34	
Buff, magnesian limestone with cauliflower cherts	14	
Cream-buff limestone, and concealed	75	
Blue limestone, foliated and crumpled, covered by sericitic shaly limestone (2 feet)	32	
White, some pink, and some bluish marble	8	
Olive-green and buff flaky shales	30	1655

Buff shaly ledges of Elbrook, probably separated by fault.

In this section there are 481 feet of ledges, mostly blue limestone above the purple shales and sandstones which have a thickness of 304 feet, with 870 feet below this purple horizon. One mile south of this section, the purple ledges outcrop in a small run valley as follows:

	Feet.	
Bluish-gray limestone and some marble.....240 feet.		
Purple shaly sandstone	30	
Buff, blocky sandstone	10	
Buff, shaly sandstone	15	
Buff, sandy shales	60	
Purple, shaly sandstone and purple shales	50	
Hard, purplish-buff shaly sandstone	15	180
Buff blocky shales..........................25 feet.		

The total section measured at this place was 750 feet, and the purple shaly horizon is much thinner than at the north. East of Halltown, its thickness is about 100 feet. A section of the Waynesboro was measured along the east-and-west road, three-fourths mile north of the Baltimore and Ohio Railroad and northwest of Engle. It is difficult in this area to secure a complete section on account of the folding:

Section of Waynesboro Northwest of Engle Station.

	Feet.
Shales and concealed	50
Yellow, smooth, platy shales	15
Purple, hard, shaly sandstone	19
Buff, platy shales with a purple tinge	25
Shaly sandstone	75
Greenish and buff sandstones, weather to shales	53
Concealed, four feet siliceous blue limestone at bottom	34
Yellow, soft Tripoli sandstone	4
Hard, sandy, and banded, blue limestone	6
Yellow, soft Tripoli sandstone	3
Greenish shaly sandstone	12
Concealed	200
Sandy shales	20
Yellow, soft Tripoli sandstone	2
Shales and shaly sandstone ledges	26
Blue, blocky limestone, some sericite	8
Shales and concealed	165
Blue and buff limestone, somewhat granular	24
Cream-buff limestone with sericitic shale leaves	15
Gray marble	3
Bluish-green and buff shales	19
Cream-buff marble	9
Bluish-white marble	12
Concealed across the valley	30
Blue, hard limestone (roadside quarry)	20

	Feet.	
Bluish-gray limestone	16	
Flaggy limestone and shales	28	
Bluish-green limestone weathers blue, and shales	40	
Yellow, soft Tripoli sandstone	3	
Shales with ledge blue limestone (5 feet) at center.	49	
Shales with ledge gray limestone (10 feet) near center)	64	
Blue limestone	8	
Yellow, soft Tripoli sandstone	5	
Gray and blue marbles, some pink-tinged	24	
Shales	20	
Bluish-white marble	3	
Platy, buff shales, and concealed	110	
Blue limestone, wavy-lined	10	1207

East of the end of this section at the top and about 500 feet distant is a blue solid limestone with a dip of 50 degrees east, which would add 375 feet to this section, so that the total thickness of the Waynesboro in this locality would be about 1,600 feet, or practically the same as northeast of Moler Crossroads. Along the road east of Engle and just north of the railroad, the thickness of the Waynesboro on the eastern limb of the anticline is approximately 1,600 feet.

OUTCROPS.—The Waynesboro Formation outcrops at a few places along the east foot of North Mountain in narrow belts where it is brought to the surface in folds in the Conococheague and Elbrook. A small elongated and irregular area is seen about a mile south of Hedgesville, showing the siliceous blue limestone and the purple shales. Another outcrop west of Arden shows the blue limestone, purple shales, and sandy, buff shales. These outcrops represent the upper portion of the Waynesboro. They may be connected in a continuous belt along this mountain, but if so they are covered for much of the distance by rock debris from the mountain.

The Waynesboro rocks cover a large area in the eastern part of Jefferson County, extending from the northeastern corner on the Potomac, southwest across the county, with a width of one to three miles, and with quite irregular boundaries. The formation is separated by a fault from the Elbrook on the west, and by another fault on the east from the Tomstown Limestone and Harpers Shale. The rocks are folded, and in many places show metamorphic alteration,—limestones being changed to marble with a development of chloritic and sericitic minerals. The thickness of the formation is about 1,600 feet.

To the west of the main outcrop belt, anticlinal folds in the Elbrook show narrow, elongated exposures of the Waynesboro, usually in the form of marble and sericitic shales or slates, with hard, siliceous, blue limestones above and below the marble.

In the northern portion of the Waynesboro area, the limestones are usually low in magnesia; while in the southern part, there are large beds of dolomite, bluish-gray to gray or buff in color, some of which are exceptionally low in silica. Siliceous, blue limestone, white vein-quartz, sandy shales, and shaly sandstones, are found throughout the formation. This siliceous or sandy structure is characteristic of the Waynesboro.

Its economic products are building stone, ballast, road material, and lime. Iron ore is found at the south along the fault-plane between the Waynesboro and Harpers Shale. It was formerly mined and smelted near Bloomery and Shannondale.

CORRELATION.—No fossils were found in the Waynesboro in the area, but Stose found a few poorly preserved shells in the sandy shale at the top of the formation in Pennsylvania, some of which were identified as *Obolus* (*Linguella*) and were regarded by him as Acadian or Middle Cambrian.

According to Ulrich (Bull. Geol. Soc., Vol. 22, p. 621), "the Waynesboro is, in part at least, the equivalent of H. D. Campbell's Buena Vista shale in central Virginia, of M. R Campbell's Russell formation in southwestern Virginia, and of Keith's Watauga shale in northeastern Tennessee".

THE TOMSTOWN LIMESTONE.

The lowest member of the Shenandoah Limestone Group is the Tomstown Limestone, named by Stose from a village in the Chambersburg Quadrangle of Pennsylvania (Folio 170). He thus describes the formation in that area:

"It is composed largely of dolomite and limestone, massive and thin-bedded, and in part cherty, with considerable shale interbedded near the base. Certain of the limestones are of sufficient purity to be burned for field lime. On account of the relatively soluble character of the formation, it forms a depression, between the mountain and an irregular line of low ridges and knobs of the Waynesboro formation farther out in the valley. Its thickness, computed from the width of its outcrop and the dip of its beds, is about 1,000 feet. . . The uppermost beds of the Tomstown, exposed just below the siliceous rock of the Waynesboro in the north and east faces of the hills north of Roadside, are massive, banded, hard blue magnesian limestones with a small amount of black chert. Within the formation occur other massive beds, chiefly magnesian or siliceous, and thinner, purer, dark limestones which in places are burned for lime."

OUTCROPS.—The Tomstown Limestone in the eastern Panhandle area is only found over small areas on the eastern border of Jefferson County. A small outcrop is found in the northeastern corner of the county in the river bend east of Moler Crossroads. A little larger outcrop lies south within the next eastward bend of the river east of Bakerton, while a long narrow outcrop extends from south of the Baltimore and Ohio Railroad, one and a half miles west of Harpers Ferry south to Millville.

In the northern outcrops the rocks are hard, blue, siliceous limestones, gray dolomites, brown limestone, with some shales. Iron ores are associated with the blue limestone and dolomite in this area. In the Millville area, the rocks are dolomites and bluish-gray limestone. To the south of this place, the Tomstown appears to be faulted out and the Waynesboro is in contact with the Harpers Shale. The thickness of the formation east of Bakerton is approximately 1,045 feet, and to the south of the railroad, it is 365 feet.

At Orebanks, one mile east of Bakerton, there are a number of large open pits from which iron ore has been removed during the past sixty years or more. A section of the rocks at this place shows:

Tomstown Section at Orebanks.

	Feet.
Bluish-gray, hard limestone, with somewhat sugary texture	45
Blue siliceous limestone	120
Blue, siliceous, hard dolomite (old ore pit)	40
Bluish-gray dolomite, siliceous, weathers white (shovel pit)	20

	Feet.	
Bluish-gray, siliceous dolomite....................	250	
Brownish limestone (blue unweathered) deep ore pit	20	
Blue, siliceous limestone........................	200	
Brown limestone (blue inside) in old ore pit......	50	
Concealed to river, but old ore pits near river bank.	300	1045

The first ore deposit east across the section is over the bluish-gray dolomite (20 feet) which has a very low west dip, almost flat. This rock is covered by 8 to 20 feet of deep-red clay in which are scattered great numbers of nodules of brown hematite iron ore, varying in size from a fraction of an inch to ten or twelve inches diameter, but most of the nodules are one inch or less. This mixture of clay and ore is removed by steam-shovels and the loose clay removed in a log-washer plant.

The underlying dolomite has a very rough, jagged top surface due to erosion and solution, so that the ore deposit extends to a very considerable depth in the fissures or crevices. Associated with this red clay are loose boulders of white to gray, fine-grained sandstone, which bear a striking resemblance to the Antietam Sandstone, and possibly represent boulder drift from some such outcrop.

The blue limestone further east in the deep ore pit is covered by a similar red clay with the iron nuggets. The ore has been removed from the crevices at this pit to a depth of 60 feet, and the blue limestone projects in nearly vertical pillars (dip 65° to 70° west), which stand 50 feet or more in height, giving a most picturesque appearance to the opening. This is a hard, bluish-gray limestone coated by weathering with a white sand, and the surface has also a brecciated appearance.

The east half of this deep pit shows similar pillars and vertical ledges of a brown, honeycomb limestone, very soft on the surface and covered with criss-cross seams of tabular crystals of dolomite, one-fourth to two inches thick. The color of the ore-bearing clay in the pit shows a marked contrast in the two portions, being bright-red over the blue limestone, and yellowish-brown over the brown limestone.

Further east are ledges of hard bluish-gray to deep-blue limestone not associated with ore and which extend to the river bank in all probability, though this portion is covered by river drift. Between the deep pit and this blue limestone are a number of old abandoned pits of large size.

To the north of this ore locality about a mile and a half, a long narrow quarry is in operation to supply a portion of the limestone for the Bakerton lime plant. The west wall of this quarry shows ledges of white marble and probably is in Waynesboro. The east wall is a dark-blue almost black limestone in places seamed with calcite, and probably represents the upper limestone in the Tomstown. It stands almost vertical or 75 degrees west, with a well-developed cleavage or schistosity, the planes dipping east 50 to 60 degrees. The rock shows a very crumpled banding and gives a peculiar fetid odor when struck with the hammer. To the east of the quarry around the point of the hill above the river bank, the hard granular dolomite outcrops.

The only other outcrop of Tomstown in the area is a very narrow belt which extends from a short distance south of the Baltimore and Ohio Railroad at a point about a mile and a half west of Harpers Ferry, southwest to Millville. The belt is nearly four miles long, and about 500 feet wide. It is bounded on the west by the low silica dolomites as quarried at Standard quarries at Millville, and on the east by the Antietam Sandstone.

Near Millville it is exposed along the Shenandoah Branch of the Baltimore and Ohio Railroad and was at one time opened in a quarry just east of the old Standard quarry east of Millville. It appears to be a part of an overturned fold and so dips east 45 to 50 degrees, passing under the Antietam Sandstone on the overturn. Its thickness at this place is about 365 feet according to the following section:

Section of Tomstown Limestone East of Millville.

	Feet.	
Waynesboro dolomites of Standard Quarry.		
Dark bluish-gray, hard dolomite....................	45	
Irregular, brecciated, dark-blue limestone..........	40	
Blue limestone, breaks shaly......................	45	
Bluish-gray, compact dolomite......................	150	
Blue, foliated limestone, some breccia..............	85	365
Antietam Sandstone.		

ANTIETAM SANDSTONE.

Below the Tomstown Limestone and the Shenandoah Limestone Group in the unbroken rock sequence is a sandstone formation which was named by Keith in the Harpers Ferry Folio (U. S. G. S., No. 10) the Antietam Sandstone from its good exposures on the tributaries of Antietam Creek in Maryland, where Keith determined its thickness as 500 feet. In the Jefferson County outcrops, it is impossible to measure its thickness.

This sandstone occurs in this area only in Jefferson County. In an unaltered condition it is white in color, in solid ledges, and fairly hard; but in its usual weathered exposures, it is stained brownish to reddish by alteration of the iron content, and it is more or less pulverulent, often only a loose mass of sand. The outcrop forms a deep, sandy soil.

The sandstone is composed of minute, rounded sand grains apparently cemented by lime carbonate. This cement is the cause of the rapid crumbling under the action of weathering agencies. The ledges are slabby, and the outcrop is marked by flat, tabular blocks usually under three inches in thickness, with a white, minutely pitted surface probably due to solution of the lime carbonate between the sand grains.

OUTCROPS.—Fragments of the Antietam Sandstone are found at several places in the eastern part of Jefferson County west of the Shenandoah River. In the red clay with the iron ore nodules over the Tomstown Limestone at Orebanks east of Bakerton, are numerous blocks of this sandstone which have probably come from an outcrop to the east of the Potomac.

Near the base of the western slope of the ridge west of Bolivar on the Charlestown-Harpers Ferry Pike, the blocks of this sandstone are very abundant and the soil is very sandy, but no ledges were found in place. Further south on this line and east of the Standard quarries at Millville, this sandstone forms cliffs with an east dip of 35 degrees. It is here a white, finely granular sandstone weathering at the surface to a buff color. Its thickness in this cliff is 100 to 135 feet, and it is overlain by sandy shales with some ledges of sandstone.

The hill to the north of the county road at Snyder Hill four miles southeast of Charlestown in the eastern bend of the Shenandoah River shows an outcrop of this sandstone, and its slopes as well as those of the opposite hill are covered in places by the Antietam Sandstone debris.

Across the river at Millville there is an outcrop of this sandstone near the lime-kilns where the limestone has been removed by erosion. The dolomite quarry north of the lime plant was worked back into the hill until this sandstone was encountered, and that portion of the quarry had to be abandoned. The blue limestone quarry above the plant does not yet show this sandstone.

In this locality the sandstone dips east 40 to 50 degrees with the limestone below it and the Harpers Shale above on the overturned fold. The sandstone in place looks fairly solid in some ledges, but it crumbles when handled and it is all in the form of crumbly sand, white in color, but more or less iron-stained.

East of the Shenandoah River the Antietam Sandstone is found on a few isolated ridges. A small area caps the hill just southwest of the Mountain Mission. A long, narrow outcrop follows the ridge from Fairmont Schoolhouse north, with two small outliers to the southwest. These ridges are covered with the tabular sandstone blocks, brownish- to reddish-white or gray, with an outside pitted crust white in color. There is usually a heavy sand deposit which, with the loose blocks, obscures or hides the ledges, so that the dip or thickness can not be determined. The sandstone debris extends far down the slopes of the ridges.

CORRELATION.—No fossils were found in the Antietam Sandstone of this area. In the Pennsylvania area near Waynesboro, Stose states that fragments of *Olenellus trilobites* were found in the scolithus sandstone and associated shales of this formation, which determined the age as Lower Cambrian.

HARPERS SHALE.

Below the Shenandoah Limestone Group and the Antietam Sandstone is a thick shale formation which is typically exposed in the hills at Harpers Ferry. From these good exposures, Keith named the formation the Harpers Shale, and described it as follows (U. S. G. S., 14th Annual Report, Part II, p. 333):

"The shales when fresh are a dull bluish-gray and weather out to a light, dirty, greenish-gray. In composition they are argillaceous and sandy, although the sandy feature is not pronounced except at certain horizons. Taking the southern half of the belt, that is to say, as far north as Harpers Ferry, there is scarcely any variation from one bed to another, and the whole is a uniform, argillaceous, slightly sandy shale. Northward from the Potomac, beds of sandstone and sandy shales begin to appear, especially in the upper portion of the shale."

OUTCROPS.—In Jefferson County which contains the only outcrop in the State, the Harpers Shale extends from Harpers Ferry and Bolivar southwest along the western slope of the Blue Ridge Mountain to the Virginia Line and beyond at the southeastern corner of the county. Its length in the county is fourteen miles with an average width of a mile and a half.

The thickness of this shale is given by Stose in the Pennsylvania section as 2,750 feet. It is estimated by Keith in the Harpers Ferry area as about 1,200 feet. He found it impossible to measure the thickness in the Harpers Ferry belt with any degree of accuracy, and states (loc. cit., p. 334):

"At Harpers Ferry, where the lithological exhibition of them is complete, the section is a hopeless tangle. The cleavage planes dip 60 to 80 degrees to the southeast, but the bedding can readily be traced in every direction and at every angle. No measure of thickness of any value whatever can be obtained here. . . . Making a liberal allowance for unrepresented portions and judging somewhat from the breadth of its outcrops, a probable thickness of 1,200 feet can be assigned to the formation."

The shales are well exposed in the heavy cuts along the Baltimore and Ohio Railroad from Harpers Ferry west, where the dip is apparently 30 to 50 degrees east, but with many minor folds and faults, and much crumpling of the folia. At the west end of these cuts, the ledges are bluish-gray, hard sandstone, which in a short distance break very flaggy and even shaly in many ledges. Interbedded are ledges of sericitic, calcareous sandstone, and greenish-gray sandstone. In places the strata are horizontal and crumpled into sharp folds with plications much contorted and twisted and broken by small faults. Further east in places the shales have weathered into slabby blocks and buff shales.

Along the Shenandoah, the freshly exposed shales are blue to bluish-green, and break out in large, slabby blocks. Greenish sandstone ledges occur here and there, and are quite resistant to weathering, with sparkling quartz surfaces. The shales all are very sandy and in solid blocks are almost a sandstone. They vary in color from the bluish-green to purple. The ledges in the river bed are bluish-green and flaggy, and form rapids and small waterfalls. Beds of quartz nodules occur in some ledges, two feet in thickness, with shales crumpled over them. Further north in the road where the shales have weathered fine and flaky, the ground is in places covered with small quartz fragments.

Across the Shenandoah, the Harpers Shale is similar in character and appearance to the Harpers Ferry cliffs. In it at the north are some very hard ledges of greenish sandstone and some fine pebble conglomerate. Bluish-green to bluish-gray ledges of shale with white vein-quartz are also seen, also ledges of sandstone in greenish sandy shales. Some of the shales look quite chloritic, but they weather buff and flaky. Most of the exposures are weathered on this mountain slope and show at the surface buff, sandy shales, flaky or blocky; but in the ravines and road cuts, the bluish-green, hard, sandy shales are exposed with sandstone ledges more or less shaly and flaggy.

North in Pennsylvania, Stose describes a heavy quartzite near the middle of the Harpers Shale which he named the Montalto Quartzite, 750 feet thick, but which thins southward and disappears. In the West Virginia area, the hard sandstone ledges occur through the formation, but at no well-defined horizon. No fossils were found in the shales, but from its stratigraphic position, it is classified with the Lower Cambrian.

THE WEVERTON SANDSTONE.

Below the Harpers Shale is a well-defined sandstone formation named by Keith from its exposure at Weverton, Maryland, the **Weverton Sandstone.** He describes it as follows (loc. cit., p. 329):

"It consists entirely of siliceous fragments, mainly quartz and feldspar. Its texture varies from a very fine, pure sandstone to a moderately coarse conglomerate, but as a whole it is a sandstone. As a whole its color is white and varies but little; the coarse beds have a grayish color in most places. Frequent bands and streaks of bluish-black and black are added to the white sandstones, especially along the southern portion of the Blue Ridge. The appearance of the rock is not modified by the amount of feldspar which it contains."

The Weverton Sandstone outcrops on the upper slope and top of the Blue Ridge from the Potomac southwest across the eastern line of Jefferson County, with an average width of one-fourth to one-half mile. Keith determined its thickness as 500 to 600 feet. This sandstone forms high cliffs near the top of the mountain, and the western slope is covered with the large boulder debris, making a very rough surface, in places almost impassable.

Across from Harpers Ferry some ledges of the Weverton Sandstone are nearly white, close-grained, and very hard, with quartz seams one to two inches thick. Most of the ledges are light-gray, quite granular, and composed of rounded grains of vitreous quartz, some of which are glassy white, a few blue, and many of an amethyst color. Feldspar is present in smaller amount, and there are also very minute grains of magnetite and a considerable amount of epidote.

Further south especially near the Chestnut Hill Schoolhouse and south, the sandstone is very dark-gray to purplish-black with blue quartz grains, and a large amount of magnetite and probably ilmenite which give the dark color to the rock. Some of the ledges have a purple-bronze color with white and blue quartz grains, one-eighth inch in diameter, but mostly small. Ledges of fine-grained conglomerate occur, and a few of these rocks are quite coarse in texture with pebbles reaching a fourth inch in size. Some ledges are dark-gray and granular, and thus resemble a granite in appearance.

In the Wilson Gap area, some ledges have weathered to a reddish-brown color, but most of the outcrops are dark-purplish, hard sandstone. A few ledges of soft, buff sandstone weathering to sand were noted here, but they are thin. Some of the dark sandstones show a distinct striation. The Weverton Sandstone is usually very hard, coarse in texture, and in this area the dark-gray to purple-gray colors predominate.

LOUDOUN FORMATION.

Below the Weverton Sandstone, Keith describes and maps another series of rocks under the name **Loudoun Formation,** which he describes in the Harpers Ferry Folio (U. S. G. S., No. 10) as follows:

"This formation is in the main a fine, dark slate, but it comprises most varieties of sedimentary rocks, such as pure limestone, shale, sandstone, and coarse conglomerates. It is also extremely variable in thickness, ranging from 10 feet at Oatlands to 800 feet four miles west of that place. The coarser and thicker deposits are found in narrow synclines scattered over the granite and schist; the thinner and finer beds are in the synclines which contain the Weverton Sandstone. Occasionally, as at Turners Gap, the formation is comparatively thick under the Weverton Sandstone. It is so named because all its varieties are well displayed in Loudoun County, Virginia."

This formation, if present in the Blue Ridge area of Jefferson County, is largely concealed by the sandstone debris, and it was not recognized, and so is not marked on the maps with this report.

Keith in the Harpers Ferry Folio gives the following outline of the origin of the Loudoun Formation which he finds well developed in the Virginia area of the Blue Ridge, and he also maps it in the Jefferson County area in two long narrow outcrops between the Weverton Sandstone and the Harpers Shale:

"The Loudoun Formation was the first sediment deposited upon the crystalline rocks, and shows therefore that the land, which had previously been exposed to wear and decay, was sunk beneath the sea. As the sea advanced over the crystalline rocks, it washed over their fragments and deposited them near their source. The currents that sorted the sediments were new and unsettled, so that the deposits were very different in different places and are much more irregular than any later formation."

IGNEOUS ROCKS.

Below the sedimentary rock series would come the Archæan and Algonkian crystalline and semi-crystalline rocks, the so-called igneous rocks, which are almost unknown in the West Virginia geology. The upper eastern slope of the Blue Ridge in Virginia is covered by outcrops of the Weverton Sandstone, but further south about opposite Kabletown, West Virginia, this slope is covered by igneous rocks, mostly schists, which extend west over the mountain crest into Jefferson County, West Virginia, at two places. One of these outcrops is in the extreme southeastern corner of Jefferson County, and the other is one and a half miles further north at Wilson Gap. The areas in this county are small, but they represent the only outcrops of igneous rocks of the Archæan in this State.

The igneous outcrop is well exposed at Wilson Gap along the county road where green and dark-brown amygdaloidal rocks occur, with cavities in the rock one-fourth inch in diameter containing quartz and epidote filling. The green rock weathers to a greenish-gray and buff color, and many of the rocks are very compact and hard. On top of the mountain are masses of green to greenish-gray igneous rocks that break blocky and are slightly banded by asbestos bands, one-tenth inch thick. The green color of the rocks is due to epidote.

In the more weathered outcrops on the east slope of the mountain are gray to white banded schists, some of which have a purplish-gray color, and they are dotted with brown oxidized pyrite grains. Further south at the other outcrop, the mountain slope is covered with igneous rock debris, but on account of the amount of this material the rock was not found in place.

Keith named this formation the Catoctin Schist from its great development in the mountain of that name, and gives its composition as follows (14th Annual Report, U. S. G. S., p. 307):

	Per cent.
Silica	41.28
Alumina	18.48
Ferric iron oxide	9.44
Ferrous iron oxide	8.20
Lime oxide	7.04
Magnesium oxide	7.486
Sodium oxide	3.523
Potassium oxide	2.208
Loss on ignition	2.740
	100.397

Keith explains the origin of these schists in the Harpers Ferry Folio as follows:

"The schist was originally a diabase or volcanic rock composed of crystals of feldspar, pyroxene, olivine, magnetite and ilmenite. The original massive rock was altered by the tremendous pressure and distortion which accompanied folding, so that the pyroxene became chlorite, magnetite, and quartz; and the feldspar was crushed and partly altered to quartz, chlorite, and muscovite. The new minerals were arranged parallel to one another and thus became a schist, characterized by the ease of splitting along these minerals. The amount of alteration increases from the Blue Ridge to Catoctin Mountain.

"The diabase from which the schist was produced was a flow of lava along the surface. It is probable that there were several eruptions of somewhat different character, resulting in the different schists which are now found. Such distinct eruptions can not be proved by the facts discoverable in this area."

PLATE XXI.—Potomac River Cliffs in Stones River Limestone at Pittsburgh Limestone Company Quarries.

PART III.

The Mineral Resources of the Eastern Panhandle Area.

CHAPTER XIII.

THE GLASS-SAND AND COAL RESOURCES OF THE EASTERN PANHANDLE COUNTIES.

GLASS-SANDS.

Glass chemically is a fused mixture of alkaline silicates, alkaline earths, and metals; or in other words, it is usually a sodium lime silicate. Almost three-fourths of the composition of glass is silica, and about one-eighth is lime oxide. In the mixture for the manufacture of glass, 52 to 62 per cent. is silica or sand as illustrated in the following table from Linton[1], showing the proportions by weight of the different ingredients used in the manufacture of different kinds of glass:

[1]Mineral Industry, Vol. 8, pp. 244-5; 1899.

	Plate Glass.	Window Glass.	Green Bottle	Lead Flint.
Sand	100	100	100	100
Salt-cake (Na_2SO_4)	...	42	38	...
Soda-ash (Na_2CO_3)	36	...	...	...
Limestone ($CaCO_3$)	24	40	34	...
Carbon (charcoal)	0.75	6	5	...
Arsenic	1	2	...	0.15
Potash (carbonate)	...	...	...	34
Red lead	...	...	...	48
Niter (sodium nitrate)	...	...	...	6
Manganese	...	...	...	0.06
Antimony	...	...	...	0.02

Lime oxide is often used in place of limestone, but it is claimed that by use of the limestone, the carbonic acid gas being thrown off in the pots or retorts passes up through the mixture giving a more thorough mixing and also that its slower action in the batch insures a better and more uniform product. The lime oxide or quicklime, or the limestone used, must be as pure as possible and free from magnesia and iron. The limestone in the form of carbonate is also more stable as the quicklime will tend to absorb some carbonic acid from the air and thus vary somewhat in its composition.

The sodium element is added in form of carbonate or soda-ash, or in the form of the sulphate called salt-cake. Linton states that at the high temperature of the retort, the carbonic acid of the sodium carbonate escapes and then the sodium unites with the sand forming a sodium silicate. In the use of sodium sulphate or salt-cake, carbon in the form of charcoal or ground coal is added so that at the high temperature, the carbonic acid gas and sulphur dioxide pass off and the sodium unites with the sand to form the sodium silicate compound. With the addition of lime, which also unites with the sand forming a lime silicate, there results a sodium lime silicate which is glass. Arsenic added also aids in removal of any carbon in the mixture and gives brilliancy to the glass. Antimony is often used for the same results.

The silica is obtained in some countries by crushing flint or quartz rock, but in this country, sand is used in nearly all the plants. The above table shows that silica or sand is the most important ingredient in quantity, and it must be of a high degree of purity, uniform in composition and texture, to secure the best results. Chemically it should contain a high percentage of silica not less than about 99 per cent. In order to secure the best results the grains of sand should be angular rather than rounded. The rounded sand grain is apt to settle to the bottom of the retort and not give a uniform mixture. Iron impurity will color the glass resulting in brown, yellow, or green shades, very objectionable in window-glass or in grades of glassware where transparency and brilliancy are required. The temperature of fusion depends on the quantity of sand added to the mixture and the hardness of the glass is largely determined by the amount of sand added. In electrical glassware the higher silica increases the resistance to conduction of the current.

The proportions of ingredients in the glass mixture, as shown in the above table, vary for different kinds of glass, and also vary within small limits in the usage of different factories, and in the use of different sources of raw materials. It becomes a very important factor in glass manufacture to select pure and reliable components and to mix these in the proper proportions. According to Linton, in the article quoted above, an excess of alkali will result in a fading glass often with rough scaly surface. An excess of lime and also alumina will cause the glass to devitrify and then become flaky and brittle. Glass which has been exposed to atmospheric action for long periods of time shows some devitrification, but an excess of lime or alumina will greatly hasten and increase this alteration. The excess of lime also tends to make the glass hard and brittle so that more work and care are required in the working of the mixture and in the annealing of the product. Too much sand requires a higher temperature of fusion and also results in an incomplete fusion with the glass full of "stone"-like pieces and stringers of opaque material.

In order to manufacture clear, transparent, and colorless glass, the materials used must be without coloring impurities of which the most common is iron. Both sand and lime are selected that are as low in iron as it is possible to obtain, but iron, at least in minute quantity, is always present in the rock materials, and it is neutralized in the glass furnace by the addition of cobalt, arsenic, antimony, nickel oxide, or manganese. Manganese is especially used in window-glass, white bottle, tableware, etc. It tends to give a light-violet color which overcomes the yellow or green tint of the iron.

In the successful and economic manufacture of glass, good materials for the mixture must be available at as low cost as possible and the plants should be located near the source of supply, but another very important factor that governs location of plants is cheap fuel. Glass manufacture requires a very high and uniform temperature which is best obtained by use of gas, natural or artificial, and natural gas is the most desirable fuel. Any fluctuations in temperature will be recorded in injury to product. The high temperature must be not only attained but maintained.

The history of the American glass industry is one of migration, and the centers of manufacture have followed the natural-gas driller. Before the modern great development of the natural-gas fields in 1887, one of the most important centers of glass manufacture was at Bellaire, Ohio, on the Ohio River and across the river at Wheeling. With the opening of the natural-gas fields in northern Ohio, these plants moved from the Ohio River Valley to Lima, Fostoria, Findlay, and later into Indiana. Some of these plants later followed the gas development further west into Kansas and Oklahoma.

With the greatly increased yield of natural gas in the West Virginia fields, many of these plants moved from northern Ohio and Indiana into this State and are still in process of migration into the gas regions of the same. New plants are springing up each year, and the State has become one of the most important glass centers of the country with some of the largest plants in the world. This State is endowed by Nature for the economical manufacture of glass. It contains the largest and most productive natural-gas fields of the world which will last for many years yet, and when the gas is exhausted, there are the rich coal fields near at hand for the manufacture of producer gas without any long hauls on this fuel, and coals that are especially rich in gaseous content. There are practically inexhaustible deposits of the purest limestone known, and large deposits of glass-sandstone almost 100 per cent. pure, and there are short freight hauls on the soda compounds from the Solvay plants near Buffalo, New York, with the possibility of making these compounds at the salt works along the Ohio River both north and south of Parkersburg. There are present, excellent railroad facilities leading in all directions. West Virginia is the natural center for the glass manufactures and each year this is being appreciated more and more.

The West Virginia glass plants center at Wheeling, Morgantown, Fairmont, Grafton, Clarksburg, Weston, Salem, Parkersburg, Huntington, Sistersville, and many smaller cities through the natural-gas belt. The lime and limestone for their use and the glass-sand come mainly from Berkeley and Morgan Counties. These two counties furnish the large bulk of material used in these plants at the present time.

To illustrate the demand for glass-sand in a glass plant, one of the window-glass companies in the State, operating a 36-blower tank running at full capacity, uses 150 tons of sand a week and 25 to 30 tons of limestone. The glass-making season extends over a period of ten months from September to June 30th, and if this plant was operated at full capacity for this period, would use 6,000 tons of glass-sand a year. No. 1 glass-sand is usually sold at one dollar a ton at the plant, and the No. 2 sand at 75 cents a ton. The No. 2 contains more impurities than the No. 1, and is apt to run higher in iron but is used in many forms of glassware as bottles, etc.

The most important glass-sand district in West Virginia is near Berkeley Springs in Morgan County, where the Oriskany Sandstone is quarried. This sandstone outcrops on a number of ridges in both Morgan and Berkeley Counties, being usually much iron-stained, impure, and often quite hard; but on the Warm Spring Ridge near Berkeley Springs, it is a snow-white crumbly sandstone or sand especially adapted to use as glass-sand.

The Warm Spring Ridge represents a portion of the eastern limb of the Cacapon Mountain Anticline and the Oriskany Sandstone on the fold is brought to the surface at the top and eastern upper slope of the ridge with a steep eastern dip of 50 to 60 degrees. It is underlain on the west by the Helderberg and Silurian Limestones, while on the eastern side it is overlain by the dark shales of the Marcellus and Hamilton. Its slopes are steep especially on the east side. This ridge extends from the Potomac River opposite Hancock, Maryland, southwest ten miles, where it is cut across by the transverse valley of Rock Gap Run, and then continues for several miles further southwest in a series of elongated hills. Its continuation north in Maryland is known as Cove Ridge. The general direction of the ridge is north 20 to 25 degrees east, and it rises in elevation from 700 to 800 feet near the Potomac, to 1100 and 1200 feet at the south, with a rather level top representing the remnant of old peneplain levels. The ridge separates the valley of Sir Johns Run on the west from that of Warm Spring Run on the east. The town and summer resort of Berkeley Springs is located in the valley at the foot of the ridge on the east and is reached by a branch of the Baltimore and Ohio Railroad from Hancock Station.

As the Oriskany Sandstone is followed north into Maryland, it is a brown impure sand rock used only for building sand, but on the western limb of the anticline on Tonoloway Ridge in Maryland, a good grade of sand is said to occur and is mined to some extent. In the counties to the south of Morgan, the Oriskany runs too high in iron and it is usually a brownish-yellow colored rock. The present development of the glass-sand industry extends from a point on Warm Spring Ridge about three-fourths mile south of the Potomac River, thence south three miles to Berkeley Springs. Good sand is found on south as far as the Virginia Line, but lack of railroad facilities beyond the town prevents any development in that direction.

This sandstone lying on the upper slopes of the ridge while the railroad follows the valley below affords favorable locations of quarries and plants with gravity haulage of the materials. The plants are usually built 200 to 300 feet below the quarry floor in tiers so that the material continually descends in the process of preparation from one level to the next below.

Water is very essential in the operation of these sand plants. It must be abundant and pure, and the Berkeley Springs area is abundantly furnished with such pure water by the springs at the town which supply the stream from which it is pumped into reservoirs at the sand plants. The waste water with its load of clay and fine sand is discharged into the run again below the sand plants, so that the stream exhibits a very muddy current toward the river, with its banks and flats covered with white glistening sand-bars. Small dams are constructed here and there to prevent too much debris being carried down to the river.

All the sand plants near the town secure their water-supply from this run, but the plant of the Pennsylvania Sand Company furthest south in the Warm Spring Valley has constructed a pipe-line to the Potomac just below Sir Johns Run, and pumps the water over the ridge to a large reservoir at the plant. The Hancock plant on the Baltimore and Ohio main line about one mile west of Hancock Station has a large spring of clear water which issues from the foot of the ridge and furnishes an abundant supply.

The district thus contains a practically inexhaustible supply of pure white sand, abundant pure water, and good railroad facilities. New plants are being built from time to time and the trade appears to be rapidly increasing.

It has been pointed out that a good glass-sand must run low in impurities. In any glass-sandstone quarry, the different ledges are apt to vary somewhat in composition and texture. Some ledges are harder than others and they may become so hard and dense as to grind in part to a flour. Where the stone thus forms a flour instead of angular grains, it gives a ropy structure in the glass and hence must be rejected. Any ledges which run too high in impurities must be rejected. The sandstone as it comes from the quarry usually contains some clay and some iron-stained masses which are separated as far as possible in the quarry, but much of it is in a finely disseminated condition and must be removed by a process of washing, and this process must be very thorough. Glass-sandstone which can be used direct from the quarry for No. 1 glass-sand is practically unknown. All the sandstone then requires a method of treatment, and there is a marked uniformity in the methods of preparation throughout this country. The steps in the process of preparation of glass-sand for the market are: 1.—Quarrying the stone; 2.—Transportation to the mill; 3.—Crushing of the sandstone; 4.—Screening; 5.—Washing of the sand; 6.—Drying of the washed sand; 7.—Storage of the finished product.

1.—The glass-sand quarries are large open cuts located cn what is considered the best portion of the sandstone stratum and convenient to a plant site near the railroad. If the quarry can be located at a level above the plant, the gravity incline to the plant adds to the economy of operation. Most of the Berkeley Springs quarries are more or less circular in outline, so that the radiating tracks center to the outlet track giving a considerable number of short tracks so that a large number of men can thus work at one time.

The sandstone here is quite crumbly and is broken down into sand or soft sandstone blocks with but little use of powder. Light shots are used to loosen the ledges and roll down a larger amount of material at the tracks. Much of the material can be shoveled into the ordinary mine or quarry cars. Pockets of loose sand occur in the ledges, some of large size. Surface portions that have rolled down into the quarry and any discolored blocks are loaded separately into cars and run through the plant separately for building or engine sand. Some of the harder and more compact ledges and conglomerates when present in ledges are thrown aside on a dump. The conglomerate or pebble rock which occurs through the sand rock in some of the quarries is separated in the plant.

At Berkeley Springs the overlying shales on the east or quarry side of the ridge must be cut through to reach the sandstone. The quarry thus has a peculiar appearance from a distance. There is against the ridge the large open face of glistening white sandstone reached by a narrow dark cut through the shales. On the west slope of the ridge where there is one quarry, the sandstone is reached by a tunnel through the underlying Helderberg Limestone.

On account of the soft character of the sandstone and its steep slope (60° E.) in this region, the stone can be pried loose with bars, and then it rolls to the floor of the quarry in large masses. A small quantity of black powder in the more solid seams completes the work. Care is required to keep the steep slope free from sliding masses which might endanger the workmen. Owing to the porous character of the rock, the quarries are dry and the pumping problem is fortunately absent.

The surface cover is light, but the sandstone for several feet below the surface is iron-stained and contains some alumina admixture, so that these upper portions are used for the common grades of sand. The outer or upper ledges of the sandstone formation are often quite hard and resistant and are not worked but are left to form the outer wall of the quarry. On account of the ease of working this sandstone and the large floor area of most of the older quarries, a small number of workmen can in a day remove a large tonnage of stone and sand.

2.—Transportation to the Plant.—The sand is loaded in 2- to 2½-ton mine cars which are hauled by mules to the top of the incline and then are let down by an ordinary cable tram working over a large wooden drum, the loaded car passing down and the empty up. Where the slope is less steep, the cars are let down by brakes to the plant and hauled back to the quarry by mules. At the Hancock plant, which has a long track from quarry to plant, a small saddle-tank locomotive is used for haulage of a train of these quarry cars. At one plant the crushing part is located at the quarry and the crushed sand is carried by water through a pipe to the main plant.

3.—Crushing of the Stone.—The softer sand will contain lumps of sandstone more or less hard, and to insure uniform grain and texture, and also to aid in the thorough intermixture of the sand from the different ledges and thereby secure a more uniform product, the sand from the quarry is run through a wet pan, which is usually a cylindrical iron pan about eight feet in diameter and ten or twelve inches high in which revolve heavy iron wheels or mullers. The pan is sim-ilar in construction to those used in potteries or sewer-pip works. Water is added and the revolving mullers break the sand lumps which become thoroughly mixed and pass through a screen opening at the side of the pan. If the sandstone is rather hard it is first crushed in a jaw crusher of Blake or other pattern and then placed in the wet pan or sent directly to the washing department.

4.—**Screening.**—The crushed sand is screened to separate any hard lumps that may remain and to insure uniform size of material. The sand is conveyed through short troughs from the wet pan to the screens which are usually revolving cylinders about three feet in diameter and ten to fourteen inches in section across. They are set vertical like a big wheel and covered with 16-mesh wire screen. The water and fine sand pass through this screen into a trough leading to the washer, while the tailings are thrown by the motion of the screen through an opening at the side and returned to the wet pan. Two screens are usually required to each pan and they are revolved at low speed.

5.—**Washing.**—One method of washing glass-sand is used at all the plants at Berkeley Springs and in the Pennsylvania plants. From the screens the sand is carried in a large surplus of water to the washing department which consists of a series of inclined wooden boxes or troughs, 10 to 14 feet long and 10 to 12 inches wide. Each alternate trough contains a rotating screw conveyor with wide blades which carry the sand from the bottom of the box to the top where it is discharged into the next trough which is without a conveyor, and is there washed to the bottom where it passes into the bottom of the next conveyor trough. There are usually four or five troughs of which two to three have the screw conveyors, in a single washer set to one wet pan. The sand leaves the last trough free from clay and impurities and passes on a belt conveyor to the drying room.

The loss of the clay and impurities is clearly seen in the change of color of the water-sand mixture in the different troughs. The liquid mass has a muddy-yellow or brown color in the first conveyor trough, and somewhat lighter color in the second, while in the last one the water is clear with the pure white sand in it. If pebbles are present in the sand, the washed product from the last conveyor is carried to another circular vertical rotating screen like those used at the wet pan, and the pebbles are separated from the sand.

6.—**Drying.**—The sand as it comes from the washing conveyors is very wet with a large amount of water held in the interspaces of the sand grains. This wet sand in some plants is dumped on a storage floor where it drains and is then shoveled on to a conveyor belt, or it falls through open doors in the floor on such a belt which carries it to the drying room.

In some plants a Cummer hot air cylinder drier is used with coke fuel. The cylinder is 22 feet long and has a capacity of 120 tons of dry sand in ten hours. Most of the plants at Berkeley Springs prefer a steam pipe drier in which a long box compartment has near its floor a series of long steam coils and the sand is dropped from the conveyor belt into this box When dry the sand falls through this box to a slowly moving belt that carries the sand through the box and dumps it at the end into a boot elevator which lifts it to an upper belt conveyor ending in turn at the storage bins.

7.—**Storage.**—Nearly all the plants in this section are equipped with large storage bins. These, in some plants, are timbered cribs elevated above the car level, or they may be steel or concrete bins. The usual plant storage capacity is around 500 to 600 tons.

Glass-sands are produced in a large number of the States and are often of very high-grade. Analyses will be given later in this Chapter of the different sands at Berkeley Springs and it may be of interest to record some of the analyses from other States for comparison with these West Virginia sands. The following analyses are quoted from the U. S. Geological Survey Bulletin 285 (pp. 456, 462) and from Linton's article in Mineral Industry:

	Ottawa.	Illinois.	Fredonia, Kansas.	Jackson, Missouri.	Penna.	W. Va.
Silica	99.45	99.89	97.94	99.52	99.06	99.86
Iron oxide....	0.30	trace	0.63	0.07	trace	0.06
Alumina		0.05		0.16	0.76	0.18

In the same Bulletin (p. 455), the following analyses are given of glass-sands used by the Pittsburgh Plate Glass Company at Pittsburgh:

Silica	99.21	98.90	98.95	98.94
Alumina	0.30	0.20	0.50	0.30
Volatile matter	0.21	0.25	0.24	0.23
Iron oxide	0.003	0.002	0.0024	0.0036
Lime oxide	0.20	0.54	0.30	0.40
Magnesium oxide	trace	0.20	0.10	trace
	99.923	100.092	100.0924	99.8736

Linton (Mineral Industry, Vol. 9, p. 239) gives the following analyses of glass-sands used in Europe:

	Nievelstein.	Hohenbocka.	Berlin.	Fontainebleau.
Silica	99.975	99.71	99.50	98.80
Lime oxide	0.010			
Magnesium oxide	0.006			
Iron and alumina	0.009		0.18	0.70

The Ottawa, Illinois, glass-sand is considered the standard glass-sand of the West and the analyses of Berkeley Springs sand compare most favorably with this sand. The iron percentage in the Berkeley Springs No. 1 sand is less than one-tenth of one per cent., so that it is safe for the highest grades of glass. The alumina is under two-tenths of one per cent., so that it is practically inert.

A description of the **operating plants** in the Morgan County district will now be given in the order of their location from the Potomac River toward Berkeley Springs. These plants were described in Volume IV of the West Virginia Geological Survey Reports issued in 1909 and with a few changes the descriptions in that volume apply to the district at the present time.

PENNSYLVANIA GLASS SAND COMPANY.

Hancock Plant.—The offices of the Pennsylvania Glass Sand Company are located at Lewiston, Pennsylvania, with sales offices at Pittsburgh and Philadelphia. The Hancock plant is located one mile west of Hancock Station on the main line of the Baltimore and Ohio Railroad, and the quarry is three-fourths mile southwest of the mill.

The Hancock mill was started over 45 years ago, and until 1903 it was owned by the Hancock White Sand Company. The plant was rebuilt in 1905 and consists of two sections, one devoted to the preparation of glass-sand, while the other section contains the pulverizer equipment for finely crushed sand. Both are substantial frame buildings, equipped with modern machinery for the preparation of sand products.

The sand and sandstone from the quarry are brought down an incline tramroad in mine cars hauled by a small locomotive, and dumped into storage bins. A large spring comes out of the ridge back of the plant and it furnishes an abundant supply of water which is quite pure and free from clay or mud, and iron.

The sand rock at the Hancock plant quarry is very friable so that it is readily crushed in an ordinary 8-foot wet pan. After crushing, the loose sand with its clay and other impurities is conveyed with water into the rotating circular screen of 16-mesh. The coarsely screened sand is carried by a trough with the water into the washing department which consists of five washing troughs to one wet pan and the sand leaves the fifth conveyor trough free from the yellow clay.

Since the rock at this quarry contains a considerable number of small flint pebbles, the washed sand from the last conveyor is carried into a third circular screen which separates these pebbles from the sand. The white sand free from pebbles is then conveyed to a Cummer drier with a daily capacity of 120 tons in ten hours. The sand from the drier is again screened through a 20-mesh screen and taken in elevators to the storage bins.

The float sand and clay from the washers is sold to firebrick factories, while the less pure sand is sold for building or for engine sand. The small pebbles from the last screen find a sale for use in pebble asphalt roofing. At the Hancock plant there are two sets of wet pans, screens, and washing conveyors, or in other words, it is a two-mill plant. The capacity of the plant is 150 tons daily of the No. 1 glass-sand, requiring for the machinery 60 to 70 horse-power. A sample of the No. 1 sand was analyzed in the Survey laboratory with the following result:

	Per cent.
Silica	99.60
Iron oxide	0.0286
Alumina	0.4214

Pulverizing Mill.—One of the interesting parts of this plant is the pulverizing mill, operated under the name of the Potomac Pulverizing Plant, where the sand is crushed to a flour of various grades of fineness.

The equipment includes two tube mills, 24 feet long and 6 feet in diameter, filled one-third full of flint pebbles. The sand from the glass-sand plant is brought over in conveyors into these mills and ground by the action of the pebbles in the rotating tube mills. The mills are lined with silica blocks weighing in all 12 tons and lasting about ten months when they must be renewed. The lining and pebbles wear down to a flour, but since they consist of very pure silica, they do not form an impurity in the crushed sand, and being sold with the sand flour part of their original cost is recovered.

The sand is ground so as to pass through 90-, 100-, 110-mesh screens, and the material is used for paint, scouring and polishing powders, and for certain kinds of soap. One mill has a capacity of 18 tons of sand flour in ten hours when crushed to pass the 110-mesh screen. The capacity is reduced to 10 to 12 tons in ten hours with a 140-mesh screen. For a few special uses as for example silver polish, the sand is crushed to pass a 260-mesh screen, and with this fineness one mill will only yield about 150 pounds in ten hours.

Quarry.—The quarry of the Hancock plant is located near the top of the mountain, three-fourths mile from the mill and 280 feet above the Baltimore and Ohio Railroad track. The whole top of the mountain is composed of the Oriskany White Sandstone while on the upper western slope is the Helderberg Limestone through which a tunnel is cut to reach the sandstone. The sandstone on outcrop is often quite hard and compact resembling a quartzite, the grains of the rock being cemented by silica, and this portion is not quarried. In the quarry the rock is very friable, often breaking into sand under the sledge. Pockets of loose white sand are found. Very little blasting is required except for the purpose of loosening large portions of the rock wall at a time. The larger blocks are readily broken by the sledge and much of the material is shoveled into the cars. Practically all the sand grains will pass through a 40-mesh sieve. The quarry is worked in a north and south direction with a strong eastern dip so that the blocks roll down to the floor of the quarry. It was formerly worked by tunnels, but the quarry is now a large open cut. It is about 450 feet long, 150 feet wide, and 100 feet deep to the main floor of the quarry, but a portion of it near the tunnel entrance is worked 25 to 30 feet deeper, the sand being drawn up an incline to the main track level. The stone lies under very little cover, but in a few places is covered by two or three feet of clay. The top of the sandstone is 30 feet above the top of the quarry which would give an exposed thickness at this place of 160 feet, but the quarry is not yet at the bottom of the sandstone.

Berkeley Plant.—The second plant of the Pennsylvania Glass Sand Company is located four miles from Hancock up the Berkeley Springs Branch of the Baltimore and Ohio Railroad. This is a two-mill plant similar in plan to the Hancock plant, only built in more compact form, and a Blake machine is used in the preliminary crushing of the sandstone. One mill includes a Blake crusher with two screens and eight washing troughs, while the other has a Blake crusher, screens, and seven troughs. The sand is dried in a long compartment heated by steam coils with 7,000 feet of heating surface and a capacity of ten tons of dry sand per hour. The daily capacity of the plant is 180 tons of glass-sand.

The following **analyses** were made of this sand. The analysis marked "A" is the No. 1 glass-sand washed and ready for the market. No. 80 is the No. 1 sand as taken from the quarry and not washed, while No. 81 is the No. 2 sand in the quarry. These analyses were made in the Survey laboratory of samples collected by the writer:

	"A"	No. 80	No. 81
Silica	99.30	99.01	98.71
Iron oxide........................	0.0314	0.02	0.16
Alumina	0.5186	0.52	0.71

Quarry.—The quarry is located 975 feet west of the and was opened in 1906. It is approached by an op through the Marcellus and Hamilton Shales 250 feet lo about ten feet wide; then through 30 feet of hard sanc which is not used. The face of the quarry is 80 to 100 feet high and the good sand extends to within ten or fifteen feet of the top. There appears to be no pebble rock in this quarry and the ledges are somewhat harder than in the other quarry with few pockets of the loose sand. It is worked toward the west. The sand is loaded in two and a half ton truck cars which pass down the incline track to the mill, and the empty cars are hauled back to quarry by a small locomotive. The plant is so arranged that the material passes down through it by gravity. Storage bins are provided for 500 tons.

WEST VIRGINIA AND PENNSYLVANIA SAND COMPANY.

West Virginia Plant.—The offices of the West Virginia and Pennsylvania Sand Company are located at Baltimore, Maryland. The West Virginia plant of this company is located one-half mile south of the last plant described. It contains three mills, each consisting of a wet pan, one screen, five washing conveyors, and the stone is first crushed in a jaw crusher. The **Keystone Plant,** located a short distance from the first, contains one mill. The sand in the West Virginia plant is dried in a Cummer rotary drier which is 28 feet long.

The composition of the No. 1 and No. 2 sands from this plant is shown by the following Survey analyses:

	No. 1 Sand	No. 2 Sand.
Silica	98.99	98.85
Iron oxide	0.0383	0.0543
Alumina	0.7717	1.0457

Quarry.—The old quarry located a short distance west of the plant was opened in the spring of 1900. It shows a face of 140 to 160 feet in height with 6 to 12 feet of surface stone much harder than the main quarry rock and which was not used. The rock dips about 40 degrees east.

In 1904 a new quarry was opened to the south of the last which shows a 125-foot face and is about 100 feet wide with room for a dozen tracks. The floor of the quarry is 200 feet

PLATE XXII(A).—Contact of Lower and Middle Stones River Limestones at Pittsburgh Limestone Company Quarries on Potomac.

PLATE XXII(B).—Cobbly Weathering of the Chambersburg Limestone 1½ Miles Southeast of Bedington.

above the floor of the mill. In parts of the quarry, red clay seams occur along the joint-planes which are one to five feet apart. The stone is worked under the ledges and then shot down in large masses. There are boulders of hard flinty sandstone through the main rock which are rejected.

Pittsburgh Plant.—The Pittsburgh plant of the same company is located three-fourths mile south of the West Virginia plant. It is equipped with Blake crusher and has two mills, one with five and the other with six washing conveyors. The sand is dried in a Cummer drier, 24 feet long and [illegible] in diameter. The glass-sand is stored in two [illegible] steel tanks resting on concrete foundations, and hold [illegible] loads or 300 tons. The daily capacity of the three plants is 400 tons of sand.

Quarry.—The quarry which supplies the Pittsburgh plant was opened in the fall of 1905 and shows a face 100 feet high and is worked in a north and south direction with a length of about 250 feet. The rock dips 50 degrees east, and the sand is loaded in cars which pass down the incline to the mill.

National Silica Works.—A pulverizing mill is located close to the town of Berkeley Springs and was formerly operated under the name of the National Mining and Milling Company, but is now known as the National Silica Works. It was formerly equipped with five short ball mills grinding the sand by action of rolling steel balls. The sand is now ground to a flour varying in degree of fineness according to the demand, in a pebble mill, 25 feet long.

SPEER WHITE SAND COMPANY.

The Speer White Sand Company built a modern mill in 1905 one-half mile north of Berkeley Springs and owns five acres of sandstone on the ridge. The plant cost $40,000 and has a daily capacity of 125 to 140 tons. The sand rock is crushed in a jaw crusher and run through a 9-foot wet pan. There are two vertical circular screens and five troughs in the washer which are ten to twelve feet long. The sand is dried in a steam coil heated drier. Mr. Speer of this company was one of the original manufacturers of glass-sand in this section but sold his former interests and was out of the field for many years.

The following analyses show the composition of the No. 1, No. 2, and the engine sands at this plant, as determined in the Survey laboratory:

	No. 1 Sand	No. 2 Sand	Engine Sand.
Silica	99.860	99.78	99.60
Iron oxide	0.068	0.09	0.12
Alumina	0.179	trace	0.06

MILLARD SAND COMPANY.

The most recent sand plant was built in 1910 by Mr. E. F. Millard a short distance north of the town of Berkeley Springs. The crushing plant is located on the ridge at the quarry and the crushed sand is washed through a conveyor pipe down the side of the ridge to the plant. At the plant the sand is washed in three troughs 12 feet long with an auxiliary washer of two troughs. The sand is then conveyed over to the drying room and is dried by steam coils and elevated to storage bins.

The composition of the No. 1 sand is as follows;

	Per cent.
Silica	99.66
Iron oxide	0.08
Alumina	0.10

BERKELEY SPRINGS SAND COMPANY.

The plant of the Berkeley Springs Sand Company was built within the town in 1891. The equipment includes an 8-foot wet pan, four washing conveyors and the sand is removed by a big reel with perforated buckets attached to the arms. It is dried in two driers 20 feet long. The capacity of the plant is 85 tons of No. 1 sand daily. The quarry is located across the county road nearly half-way up the ridge and shows a face of rock 120 feet high. It is worked in an open cut about 200 feet long and 50 feet wide and is reached by a short entry passing through a hard yellowish outcrop of the sandstone. The following Survey analyses show the composition of this sand:

	No. 1 Sand.		No. 2 Sand.
Silica	99.580	99.120	99.580
Iron oxide	0.068	0.154	0.018
Alumina	0.199	0.211	0.153

These analyses show the samples as taken were all good sands and the No. 2 was in reality a No. 1. There is not much difference in the grades of sand from the washer except when the surface ledges are included. The No. 2 sand is usually a little stained with iron.

GREAT CACAPON SILICA SAND COMPANY.

The Great Cacapon Silica Sand Company of Pittsburgh opened a quarry in the White Medina Sandstone in 1904 on the west slope of Cacapon Mountain, one mile and a half east of Great Cacapon Station, which was operated for only a short time and has since been idle. The product was not very satisfactory. Much money was expended on the plant and quarry and on prospecting further south on the mountain. The plant is of frame and consists of a series of connected buildings extending up the mountain slope. The material coming down the slope from the quarry would pass from one level to the next lower in the process of manufacture thus utilizing gravity and avoiding elevators. The crusher was on the upper floor, then came the screens and washing plant, with storage bins below and still above the car floor level. The plant was designed for labor and power saving so that the product could be prepared at a low cost.

The plant is located at the side of the main line of the Baltimore and Ohio Railroad which is 400 feet below the level of the county road on the mountain where the main incline track started. From the county road an open cut was driven south into the hard sandstone, 150 feet long, to the second incline which extends to a level 75 feet higher. Here a second open cut 55 feet long and six feet wide extends back to the open quarry. The quarry floor is thus 475 feet above the railroad. The quarry is about 100 feet wide, worked back 75 feet, and 40 to 50 feet high. At the south end of the quarry a tunnel is driven five feet high and 15 feet wide in a softer ledge of sandstone which was apparently used at the plant.

The quarry shows a series of ledges dipping 8 to 15 degrees west, which are quite hard, compact, and almost quartzite, being much iron-stained. Ledges of softer sandstone quite white also occur and these were regarded as valuable sand deposits and it was hoped they would increase in thickness as the quarry was opened but this was not the case. The tunnel was apparently driven in one of these softer ledges and a sample was taken here for analysis (76).

The sandstone when opened was supposed by the owners to be the same as at Berkeley Springs, but instead of being the Oriskany, the outcrop on this mountain is the White Medina probably 1,600 to 2,000 feet lower in the geologic column of strata. This hard sandstone when crushed breaks down into a rock flour which lacks the angular grains required in a good glass-sand. The floury character of so much of this crushed material tends to give a ropy character in the glass and prevents a uniform mixture.

The main mass of this sandstone as exposed in this quarry is not suitable for glass-sand. It is possible that the softer ledges might be used, but the expense of their separation would be too great for any economical work. The material probably would be useful for other than glass purposes when finely ground to a flour in tube mills as is done at Berkeley Springs. The question then would be whether there was a sufficient market to justify this form of manufacture. It is indeed unfortunate that with this fine plant and the great advantage of gravity system and nearness to the river for water-supply that the material is not of different grain and texture. The chemical composition shows it to be quite pure sand and the entire trouble appears to be in the texture.

Prospect openings have been made over the mountain to the south with hopes that a better sand rock would be found. Pockets of the softer sand were found but they probably with depth pass into the harder strata. There is no indication that the Medina Sandstone on Cacapon Mountain will furnish any profitable deposits of good glass-sand, and hence there is not much encouragement for the work along this particular line. The chemical composition is shown by the following analyses.

The first one was of selected sand from the quarry after washing. No. 76 is the white softer sandstone at the roof of the tunnel in the south end of the open quarry:

	Washed Sand.	No. 76	No. 61 North Mtn.	No. 101 Gerrards-town Gap.
Silica	99.86	99.15	98.03	98.76
Iron oxide	0.66	0.07	1.69	0.18
Alumina	0.23	0.56		0.54
Lime carbonate		0.05	0.32	0.10
Magnesium carbonate		0.03	0.15	0.11
			100.19	99.69

It is interesting to note that the White Medina Sandstone forming the crest of North Mountain several miles to the east is like this outcrop a very pure sandstone (No. 61), but the outcrop there is quite narrow and the rock is also a very hard quartzose sandstone, which when crushed would have similar faults. No. 101 shows the composition of the Medina near the crest of the mountain back of Gerrardstown at the Gap.

This property was leased early in 1916 by the Harbison-Walker Refractories Company of Pittsburgh, and the crude sandstone rock is loaded and shipped to their plant at Layton near Pittsburgh, where it is crushed and mixed with 8 per cent. of lime and made into silica brick. Their tests show this hard Medina Sandstone to be especially adapted to this product.

ORISKANY SANDSTONE SOUTH OF BERKELEY SPRINGS.

There has been no development of the Oriskany Sandstone to the south of Berkeley Springs as that is the terminus of the railroad, but the sandstone extends for many miles to the southwest along this ridge to and beyond the Virginia State Line.

The top of the ridge and the upper eastern slopes are composed of this sandstone with an eastern dip less steep to the south. As far south at least as Rock Gap eight miles south of Berkeley Springs, the sandstone is a crumbly rock much iron-stained in places and mixed in the exposed surface portions with clay and soil. Most of these impurities could be washed out and below the surface the rock is probably as white and pure as to the north of the town. Water could be obtained from Sleepy Creek, or by impounding such runs as Rock Gap, Sir Johns Run, etc. The extension of the railroad up the valley would doubtless open a number of new deposits, so that the reserve supply of No. 1 glass-sand is very great in Morgan County.

Where Rock Gap Run cuts across the ridge the sandstone is well exposed as a crumbly white rock. Even the apparently solid ledges crumble when struck with the hammer and it is almost impossible to secure a solid block of the sandstone. The analysis of the average outcrop here unwashed is shown by sample No. 69.

The rock is exposed on the road which crosses the ridge two miles north of Rock Gap. The road here is deep in loose sand and in exposures unmixed with surface debris is a white friable sharp sand, and the ledges readily crumble.

At the road crossing the ridge two miles further north or four miles southwest of Berkeley Springs, the sandstone presents a similar appearance (No. 71), and good sand could be obtained at this place. This road, while open, is practically abandoned on account of the depth of loose sand and the sharp hill inclines over the loose rock strata.

About one and a half miles south of town, the sandstone is quite white with a number of fairly solid ledges but which are easily broken. The sand also occurs loose and has a similar appearance to the other outcrops further south. Its composition is shown by analysis No. 73.

At the top of the ridge south of the road and just west of town, a small quarry has been opened for many years from which sand is hauled to town for building purposes. The whole quarry is a mass of loose sand and crumbly sandstone ledges much stained at the surface by iron and clay. The sand if washed would be quite white and pure (No. 75). No. 170 is the sandstone back of Ridge Store, 14 miles south of Berkeley Springs.

	No. 69	No. 71	No. 73	No. 75	No. 170
Silica	99.00	99.20	99.23	98.43	99.32
Iron oxide	0.07	0.15	0.13	0.09	0.12
Alumina	0.55	0.31	0.31	1.05	1.01
Lime carbonate	0.04	0.04	0.05	0.04	0.25
Magnesium carbonate	0.05	0.04	0.05	0.05	0.04

These different analyses made of the crude material show that by proper preparation the sand could be used for glass-sand. The belt extends south of Rock Gap and would probably show similar characters for quite a distance at least, but the tests were not carried further south as the additional length of outcrop of eight miles tested for the entire distance or double the length now developed to the north of the town, is sufficient for any demand in any reasonable future time, and it is safe to say that the Berkeley Springs glass-sand deposits are practically inexhaustible. This southern area will become available whenever railroad connections are furnished, and it illustrates the wonderful resources of this district in this line of raw material.

OTHER OUTCROPS OF ORISKANY SANDSTONE.

The Oriskany Sandstone also outcrops along Tonoloway Ridge to the west of Cacapon Mountain and Cacapon River Where this ridge is cut through in the new road at Ziler Ford, the sandstone is very white and full of casts of shells and resembles the Warm Spring outcrops, though in these fresh exposures the rock is harder.

This sandstone is worked just north of the river in Maryland where it is more or less impure and used for building sand. Further north on the ridge, it is said to be very white and pure and to resemble very closely the Berkeley Springs sand, and plans have been made to develop it.

Mr. N. Q. Speer has recently prospected this sand on Tonoloway Ridge, and a sample of it analyzed in the Survey laboratory yielded the following results:

	Per cent.
Silica (SiO_2)	99.86
Iron oxide (Fe_2O_3)	0.016
Equals metallic iron	0.012
Calcium carbonate ($CaCO_3$)	0.04
Magnesium carbonate ($MgCO_3$)	trace
Loss on ignition	0.05
	100.00

"This is a high-grade sand, well suited for the manufacture of flint and crystal glass."

A narrow outcrop of Oriskany follows the western upper slope of North Mountain nearly to the Potomac River, but it is quite narrow and apparently rather impure and irregular in texture. It also forms outcrops on both sides of Ferrel Ridge. West of Butts Store and near the top of the ridge, it is quite pure in unwashed samples according to the analysis (No. 50). It contains 97 per cent. silica and part of the 2.1 per cent. of iron and alumina would wash out.

As traced south on this ridge, it contains more lime, but about the same amount of iron and alumina as shown in the sample (No. 58) taken two miles west of Tomahawk. The sandstone has a similar appearance at a number of places near Tomahawk but it is higher in lime, and at the spring near the store it is a limestone and would be taken for the Helderberg except it contains Oriskany fossils (No. 54). This calcareous phase of the sandstone is also shown in the outcrop three-fourths mile west of Cherry Run (No. 65) which is either to be classed as a siliceous limestone or a calcareous sandstone with Oriskany fossils.

If any demand ever should arise for the use of glass-sands in this portion of Berkeley County, the sandstone on the upper portion of Ferrel Ridge would be available, but there is now no railroad in this valley and the outcrops are narrow.

	No. 50	No. 58	No. 54	No. 65
Silica	97.29	96.34	6.65	36.80
Iron and alumina	2.10	2.25	1.08	1.58
Lime carbonate	0.45	1.07	92.09	61.38
Magnesium carbonate	0.20	0.31	0.64	0.48
	100.04	99.97	100.46	100.24

STATISTICS OF SAND INDUSTRY IN WEST VIRGINIA.

The following table shows the production of sands in West Virginia for a period of years from 1903 and is taken from the Reports of the U. S. Geological Survey. The larger portion of these sands comes from the Berkeley Springs area, though there are several other sections producing a very considerable tonnage of sand, as near Morgantown, Craddock, Holmes, etc. The State has held third rank among the States of the Union in the production of glass-sand for many years, being surpassed by Pennsylvania and Illinois. In 1911 it ranked ahead of Illinois, taking second place that year. In 1913 it reached first in total production though slightly behind Pennsylvania in value:

Year.	Glass-Sand.		Engine Sand.		Building Sand	
	Short Tons	Value	Short Tons	Value	Short Tons	Value
1903	65,524	$107,601	8,831	$ 7,125	4,879	$ 4,269
1904	74,469	102,684	7,310	7,310	89,916	39,556
1905	155,052	225,734	33,503	28,536	77,488	42,232
1906	158,093	227,225	31,844	21,267	123,259	62,346
1907	171,338	225,003	78,985	47,400	151,622	70,450
1908	145,782	174,834	30,520	18,012	121,321	58,153
1909	169,731	205,102	27,896	22,700	135,537	84,769
1910	235,784	282,267	47,777	29,280	231,535	87,109
1911	268,368	313,758	29,949	20,606	205,194	93,037
1912	244,881	287,038	60,442	34,182	171,269	81,019
1913	534,600	668,214	133,390	94,017	195,115	99,950
1914	233,024	269,602	96,675	46,578	251,278	108,112
1915	264,076	280,702	77,794	36,259	185,113	83,821

COAL RESOURCES OF THE EASTERN PANHANDLE AREA.

In the Meadow Branch Mountain area and on Sideling Hill, the anticlinal folds have brought to the surface Lower Carboniferous or Mississippian rocks consisting of hard sandstones and shales. In these rock areas there are also exposed black carbonaceous shales with small coal seams which have been tested and exploited for over 75 years with no valuable economic returns.

Sideling Hill.

The coal seams in the Rockwell Formation on Sideling Hill are quite thin and the coal is high in ash and very crumbly on exposure. Small mines were opened years ago to supply a small local trade and even these did not yield much coal. The openings have long been abandoned and have caved in so that at the present time it is impossible to see the coal in place. The old dumps show a mass of disintegrated coaly black slate and flakes and splinters of slaty coal with a piece here and there of lump slaty coal, but no good coal was observed. In this area of West Virginia, the only mines were located on Rockwell Run southeast of Orleans Crossroads. Here a number of pits were sunk and one long tunnel was driven a few hundred yards along the outcrop starting in about the level of the run. Recently a shaft was sunk to intersect this tunnel vein but at a depth of 25 feet it was abandoned before reaching any coal or even black slate.

The old dumps show a large amount of black slate and carry fossil ferns which have been correlated with the Pocono, so that the Rockwell Run Coal is Pocono in age. There is an impression in this part of the country that valuable seams of coal can be found, but there is no evidence upon which to base such an opinion. Any coals found here will be of little thickness and very friable and slaty,

Stose (Pawpaw-Hancock Folio, p. 167) was able to measure this coal on Sideling Hill north of the Potomac River in Maryland in some of the old mines that were still open, and he secured the following section:

Section of Coal and Shales, Sideling Hill (Stose).

	Feet.
Hackly dark shale	8½
Thin coal and shale	1½
Hackly dark shale and thin concretionary sandstone beds	50
Dark "shoe peg" shale	15
Hard well-bedded shale	10
Thin-bedded ripple-marked sandstone and shales	5
Hard hackly dark shale	6
Granular sandstone	5
Hard dark-gray crumbly shale	5
Massive coarse sandstone	

Stose describes the coal as "composed of very thin sheets of slickened coal mixed with black carbonaceous shale". The thickness of the thin coal and the shale was only one and a half feet. The reported thickness of this seam in this area of three to four feet is due to the probable inclusion of the dark shales with the coal. There is no indication from the Maryland measurement or from the study of the old dumps to justify the exploitation of this coal seam, and it would not be profitable to open even for a local trade. All evidence tends to show there is no coal of economic value in the Rockwood Formation in these counties, and no coal of value in the Sideling Hill area.

Meadow Branch Field.

The coals of the Meadow Branch field in Morgan and Berkeley Counties have been known for a very long time and much money has been expended in prospect work upon them. The results have been more encouraging than in the Sideling Hill area, as the coals are in thicker veins and of very good quality except for the close slate admixture. The coal has been at various times called an anthracite, semi-anthracite, and even semi-bituminous.

As described in a preceding chapter on the Pocono Formation, the rocks outcropping in the Meadow Branch Field include the hard white Purslane Sandstone which forms the crest and inner eastern slope of Sleepy Creek Mountain and the crest of Third Hill Mountain. The Rockwell Formation below the Purslane is exposed on the outer slopes of both mountains, but no coal seams have been found in that formation in this area.

The two mountains are the outer limbs of a rather broad but sharp syncline and Meadow Branch lies in this synclinal basin near the axis of the fold. The Purslane thus dips down under the Meadow Branch Valley, coming up again in an overturn on the upper east slope of Third Hill. In the Valley there is exposed the coal-bearing Hedges Shale covered to the eastern side of the valley by the overlying Myers Red Shales. These coal shales following the eastern rising limb of the syncline again appear near the top of Third Hill Mountain where they stand almost vertical in places.

The Hedges Shale is about 180 feet thick and consists of sandy buff shales and thin shaly sandstones with some black shale and coal. There are apparently three coal seams, one near the bottom, one above the middle, and one near the top of the formation. Most of the prospects and shafts appear to have reached the lower coal near the base of the formation and this has been regarded as the most promising seam. The coal has been prospected in the valley and at the top of the mountain, but most of the work has been on the mountain where the coal was supposed to be much thicker (which is doubtful) since further in this part of the outcrop the coal is much more crushed and thereby intermixed with slate.

The Meadow Branch Syncline rises both to the north and to the south and the area of coals is not very long. The Hedges Coal Shale following the synclinal fold has an east dip of 30 to 40 degrees on the east basal slope of Sleepy Creek Mountain and is almost horizontal in the basin of the creek valley and on the overturn at the top of Third Hill dips east 70 degrees. The field has been prospected at various times for the past 75 or 80 years, and reports on the coal have been made by expert engineers and geologists from time to time, which practically all agreed in the conclusion that the economic and successful mining of this coal was an exceedingly doubtful proposition.

Prof. W. B. Rogers[1], one of the great geologists of this country, as early as 1835 stated that openings have been made on this coal near Sleepy Creek, and anthracite of very purest character obtained. He gave the results of an analysis made on this coal by Prof. H. D. Rogers which showed 4.94 per cent. ash, the remainder being volatile and combustible matter.

Later in 1838 (p. 225) Professor Rogers made a more detailed survey of this coal field, determining the mountain structure and correctly placed the coal formation in the Pocono division of the Carboniferous. His details of structure

[1]Geology of the Virginias, reprint, 1884, p. 99.

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"Between Sleepy Creek and Third Hill Mountains at an opening on the Meadow Branch by Embry and Cushwa, a shaft 45 feet deep passed through three seams of coal from one to three feet thick, and a tunnel from the hillside strikes a four-foot seam below. The coal appears to be of fair average quality, but somewhat broken up and intermixed with slate. There was nothing in this opening to lead me to the conclusion that the problem which has been on hand for the last forty or fifty years, as to the coal being here in paying quantities, was at last satisfactorily solved."

At this date then in 1876, the value of the coal was regarded as very doubtful. In the next year, 1877, Persifor Frazer in the Proceedings of the Academy of Natural Sciences (Vol. 29, p. 16) gives some notes on a visit made by him to this coal field and he states the coal resembles that of some Schuylkill anthracite, but that the exposures are few and shallow and much washed in, so that observations were poor. He gives the following analysis of the coal but does not give the exact opening the sample was taken from. An analysis of the coal is also given in Bulletin 42 (p. 146) of the U. S. Geological Survey from this field but no notes are given further than the mere analysis:

	Frazer.	U. S. G. S.
Free carbon	86.78	81.20
Volatile hydrocarbons	7.66	10.90
Moisture	0.21	2.30
Ash, light-gray color	5.35	5.60
Iron under 1 per cent.		
Sulphur	not det.	0.785

More recent analyses of this coal will be given later in this section.

In 1902, Mr. William Griffith, a well-known coal geologist of Pennsylvania, published a description of the Meadow Branch Coal Field (Mines and Minerals, Feb. 1903, pp. 293-4) which is republished in full in the Coal Reports of the West Virginia Geological Survey, Volume II (p. 704-8) and Volume II-A (pp. 3-8). Mr. Griffith describes the location of the area, topography, and general geology. He describes the coal prospects especially on Third Hill Mountain over a distance of 12 to 15 miles. From his studies along this mountain and his experience in other coal fields, he concludes:

"While these provings have been very alluring to prospectors, and considerable time and money have been spent, both in shafting and boring with diamond drills, as yet no coal beds have been found of sufficient value to warrant the expense necessary for their development. The true Carboniferous Formation, which includes the productive coal measures of Pennsylvania and West Virginia, is much higher in the geological series of rocks than the Pocono in which the coal in question is found. And in Pennsylvania no anthracite coal of workable thickness has ever been found in the Pocono rocks. . . .

"As a result of the above facts, and the known geological position of the beds of Third Hill, in connection with their steep dips (usually inverted) and the evident distortion and folding of the measures, we must expect to find the coal beds more or less crushed throughout the region, and in much the same state as the crushed and faulty coal of the Pennsylvania anthracite beds. In addition to this, the beds would probably be found more irregular and erratic as to thickness and continuity, existing more or less as pockets, and very uncertain as a basis upon which to make a large investment of capital necessary to development for railroad shipment."

At the time of Mr. Griffith's visit to this section, some of the openings were accessible and his descriptions of these exposures since fallen shut or filled with water are of especial interest. At the south end of the area near the road across the mountain to the Myers place there is a small infolded area of the coal-bearing shale in which several prospects were opened, and Mr. Griffith describes this exposure at that time as follows:

"At this point a distinct basin is found in the hard Pocono rocks near the crest of the mountain. The basin is about 500 feet wide and shallow. The proving shaft was about eight feet square, 50 or 60 feet deep, and sunk in the coal outcrop on the east margin of the basin. The writer was lowered into the shaft by means of a bucket and rope attached to the hoisting engine, and found the coal bed — which was supposed to be about 10 feet thick — much crushed and faulty, as has before been mentioned, and practically worthless. Near the bottom of the shaft, the bed seemed to be parted by layers of fire clay and slate, and in worse condition than at the top. This shaft was shortly afterwards abandoned.

"On the western outcrop of this narrow basin, the rocks were regular dipping to the east about 40 degrees. A short tunnel had been driven westward into the hill, cutting a bed of coal about 2½ feet thick. The writer examined this seam, after having the tunnel cleaned out, and found that though the dip was regular and the bed right side up, the coal was in much the same condition as in the shaft; and that while a small quantity had evidently been mined out and used locally by farmers in the valley, the bed was virtually valueless for general development."

The coal is thus seen on the overturn to be locally greatly thickened in the crushing movement, but still worthless, while in the less disturbed area on the west its thickness is very small and also badly crushed and broken. There is not much encouragement in these observations on the actual coal seam in the shaft and tunnel for exploitation. Mr. Griffith further points out how money has been expended in prospecting for this coal with no attention paid to its structure so that tunnels and borings were made outside of the basin to encounter a supposed vertical seam as shown at the surface at the overturn. He states that,

"Previous to sinking the shaft above mentioned, much money had been spent in driving a tunnel horizontally into the east flank of the mountain, about half-way down, all the way through the red rocks of No. IX, in hopes of cutting the vertical coal bed 200 or 300 feet below the surface. The tunnel (about 7 by 8 feet) was driven several hundred feet into the mountain, and at its end diamond drill holes were bored horizontally 100 feet or more, until the water pressure forced the drills out and stopped further progress of the work. The tunnel would not cut the coal if it had been extended clear through the mountain, as it was probably far below the bottom of the shallow basin containing the bed. A diamond drill hole had also been bored in the top of the mountain, but outside of the coal basin."

Further north near Hedges Mountain on the headwaters of Cherry Run where the strata are overturned with a resultant dip of 80 degrees to the east, Mr. Griffith describes the openings as follows:

"The outcrop has recently been cut by a drift on the north side of the Cherry Run Gap of Short Mountain, and more recently at a shaft in the gap southwest of Norrington's peach orchard. This shaft is about 5 feet by 8 feet, and it is said to be over 50 feet deep. Coal was struck about half-way down and it is said to be about 4 or 5 feet thick. A number of tons was sold to the farmers near by for upwards of $4 per ton, and was pronounced of satisfactory quality. Although this shaft was filled with water and we were not permitted to examine the coal in place, we were able to judge of its structure and condition by the heap of coal, dirt, etc., still piled near the top of the shaft. It is unquestionably in the same crushed and faulted condition at every other point of the region, where openings have been made."

In order to test the coal in the valley itself where the dip was only slight in the bottom of the syncline, Mr. Griffith had an opening made near the Meadow Branch west of the Myers place which showed the following:

PLATE XXIII(A).—Conococheague Limestone, Showing Siliceous Banding near Prospect Hill.

PLATE XXIII(B).—Waynesboro Limestone One Mile South of Hedgesville.

"The bed of coal was 3½ to 4 feet in thickness, lying in good position between regularly dipping rocks, but the coal was of the same crushed and slippery character referred to above; and while the coal would probably burn good, the crushed condition would cause an excessively large percentage of fine coal, such at pea, buckwheat, and dust, which would reduce the market value of the product, as would also its soft and friable nature; on account of which it could not stand much handling, but would readily crumble, causing much culm and waste."

Mr. Griffith has had a long and successful experience in the anthracite fields of Pennsylvania, and he came into this field unbiased and made a careful study of it and gathered all the information possible, so that his final conclusions from the study of the field are of much interest and should have much weight. These conclusions agree with those made in the early days by Rogers and by the various investigations after the time of Rogers, and are given in the following extract from Mr. Griffith's report:

"Our investigations of this curious coal field led us to regard the coal beds of Third Hill as a sort of natural curiosity or geological freak, and, owing to uncertainty as to thickness and continuity, and probable unreliable or pockety and faulty nature of the beds, their economical value is small. There can be no doubt that the above-described crushed condition of the coal beds extends throughout the region, including the deeper parts of the seam, far below the surface, as well as near the outcrop. Of course, if the coal beds in Third Hill were proved to be 3 or 4 feet thick or more, continuous and reliable, the large investment required to develop for railroad shipment would be justifiable, notwithstanding the crushed condition of the coal, for the location, excellent railroad facilities, and good market, at high prices, would go a long way toward counterbalancing the loss due to poor fracture of faulty coal. But to attempt to prove the reliability of these seams as to thickness, continuity, etc., would require a considerable expenditure which would, in the writer's opinion, be very likely to result unfavorably."

Mr. M. R. Campbell, of the United States Geological Survey in 1903, one of the able coal geologists of that Survey, made a detailed examination of the Meadow Branch Coal Field (Bull. 225, pp. 330-344). He describes a number of coal openings, one of which known as the **Shepherd Shaft** was located near the southwestern extremity of the mountain and on the eastern side of the synclinal basin where the rocks were nearly vertical. The coal was cut in this shaft at a depth of 42½ feet and the section was measured by Hammond Hunter as follows:

	Ft.	In.
Coal	5	9
Sandstone	1	6
Coal	4	0
Shale and coal	3	8
Coal	2	2
Shale	4	0
Coal	3	8
	24	9

which gives a total thickness of 15 feet 7 inches of coal.

At the **Nihiser Shaft,** 108 feet deep, located two miles north of Pinkerton Knob where the rocks dip southeast 70 degrees, Mr. Campbell gives the following section as measured by Mr. Hammond Hunter:

	Ft.	In.
Coal	4	4
Shale	1	4
Coal	4	0
Shale	1	7
Coal	2	0
	13	3

which gives a total thickness of coal of 10 feet 4 inches.

The **Chappelle Shaft** was located on the west side of Short Mountain near the north end of the basin and the following section was measured by Campbell:

	Ft.	In.
Coal badly mixed with slate	4	4
Clay	1	3
Coal with two or three irregular partings	5	3
Clay	0	6
Coal (reported)	11	0
	22	4

The lower portion of the seam could not be seen on account of water and debris, but it was reported to be 11 feet thick. If this reported thickness at the base is correct there would be in this opening 20 feet of coal which is identified by Campbell as the lower seam of the coal shales. The thickness is much greater than usually found in these openings and probably represents a local thickening in a basin.

At the foot of Sleepy Creek Mountain northeast of Whites Gap, Campbell measured the following section:

	Ft.	In.
Coal, badly weathered	1	6
Clay	0	1
Coal, weathered	0	8
Clay	0	3
Coal	1	0
	3	6

which shows a decrease in thickness to 3 feet 2 inches of coal, and Campbell states that one mile to the south, the coal measured 3 feet 1 inch and was badly weathered.

Campbell sampled the coal from the Chappelle Shaft and the analyses were made in the laboratory of the U. S. Geological Survey. No. 1 represented the run-of-mine coal after the larger lumps of slate were removed. No. 2 was made from selected lump coal. The No. 3 sample was taken on top of Third Hill Mountain on the road to Myers cabin, and about eight miles south of the Chappelle Shaft:

	No. 1	No. 2	No. 3
Fixed carbon	73.20	79.64	76.37
Volatile carbon	9.00	11.51	12.31
Moisture	1.94	1.04	1.78
Ash	15.86	7.81	9.54
	100.00	100.00	100.00
Sulphur	0.91	0.81	0.54
Phosphoric oxide	0.04	0.02	0.02
Fuel ratio	8.13	6.92	6.20

In the present work two samples of coal were taken from the dumps, one at the Chappelle Shaft near the top of Short Mountain, the other at the Meadow Branch Shaft, just east of the run and opposite Whites Gap. A sample was also taken from the old opening one and a half miles south of Myers cabin (103), also from the Wheeler mine a half mile south of the Hampshire grade road west of Shanghai (102). These coals have been exposed to weathering action for at least three years. They were analyzed in the Survey laboratory with the following results:

	No. 66 Chappelle Shaft.	No. 87 Meadow Branch.	No. 103 South of Myers.	No. 102 Wheeler Mine.
Fixed carbon......	81.45	81.37	81.25	82.80
Volatile matter...	11.51	11.02	11.92	10.86
Moisture	0.59	0.46	0.41	0.48
Ash	6.45	7.15	6.42	5.86
	100.00	100.00	100.00	100.00
Sulphur	0.78	0.66	1.26	0.84
Phosphorus	0.041	0.015	0.003	0.007

When this sample from the dump is compared with the one taken from the mine by Campbell, it is seen that the analyses agree rather closely and that there has been practically no loss by exposure. The coal is durable in composition on exposure. The analyses show a high percentage of combustible matter, a fairly low ash and coal not high in sulphur and phosphorous. Chemically this is a very fine coal if the slate is separated.

Classification of the Meadow Branch Coal.—As has been stated in an earlier part of this discussion, this Meadow Branch Coal has been called an anthracite, a semi-anthracite, and even a semi-bituminous coal. The classification of coals is a subject of considerable discussion and of considerable disagreement among coal chemists and coal geologists. The old classification was by percentage of fixed carbon in the coal, and five varieties of coal with a possible sixth at the bottom were recognized. In 1877, Persifor Frazer on the Pennsylvania Survey used the fuel ratio (percentage of fixed carbon divided by the percentage of volatile matter) as the basis of classification, and this method has been very generally used since that time. The following groups were thus divided:

	Fixed Carbon. Per cent.	Fuel Ratio.
Anthracite	100 to 90	100 to 12
Semi-anthracite	90 to 85	12 to 8
Semi-bituminous	85 to 75	8 to 5
Bituminous	65 to 50	5 to 0
Lignite	50 to 45	
Peat....................	Less than 45	

Objections are made to both methods of classification. Campbell objects to the fuel ratio classification in that it leaves out of account the lignite or brown coal so important in many parts of the West, and also in the grouping together under bituminous coals the low-grade coals of parts of Iowa and Missouri with the great Pittsburgh vein and New River Coals thus suggesting their equal value in the classification.

Recently Professor Parr[1] in Illinois has proposed a coal classification based on the ratio of volatile carbon unassociated with hydrogen and the total carbon with the following groups:

Anthracite...... volatile carbon—carbon ratio below 4 per cent.
Semi-anthracite, volatile carbon—carbon ratio between 4 and 8 per cent.
Semi-bituminous, volatile carbon—carbon ratio from 10 to 15 per cent.
Bituminous (into 4 sub-groups) ratio from 20 to 45 per cent.

A number of analyses have been given above of the Meadow Branch Coals. The fuel ratios according to these analyses are as follows:

Frazer.	U. S. G. S.	Campbell, U. S. G. Survey			W. Va. Geol. Survey	
		No. 1.	No. 2	No. 3.	No. 66	No. 87
11.33	7.45	8.13	6.92	6.20	7.07	7.38

By applying the Frazer classification above to these coals, they are found in no case to fall in the anthracite group, and with the exception of the Frazer analysis and the No. 1 of Campbell, they fall in the semi-bituminous class, yet their texture and structure indicate that they should be regarded as above this class and they probably would be best classified as semi-anthracite coals.

Coals are examined in two ways known as the proximate and ultimate analysis. The proximate analysis separates the coal into the following components: Fixed carbon and volatile combustible matter which determine the heating value of the coal, moisture and ash which give no fuel value but are inert parts, sulphur which in large quantity may prove injurious in the furnace. This is the usual form of analysis and the above coal analyses are proximate..

The ultimate analysis separates the coal into its essential

[1]Bull. Ill. Geol. Survey, No. 3, pp. 51-52; 1906.

chemical elements: Carbon, hydrogen, oxygen, nitrogen, sulphur, and ash. Its use in determining the value of a coal is not so apparent to the untrained eye as the proximate analysis, and it is therefore more rarely made and used. It is the more accurate method of analysis, and when such analyses are made over the country, they will afford a scientific basis for the comparison of the various coals.

An ultimate analysis was made in the Survey laboratory of the coal from the Meadow Branch opening to east of Whites Gap through Sleepy Creek Mountain with the following results:

	No. 87 Per cent.
Carbon	86.14
Hydrogen	3.27
Oxygen	2.14
Nitrogen	0.64
Sulphur	0.66
Ash	7.15
	100.00

With the total carbon as determined by the ultimate analysis, the more modern classification of Professor Parr can be applied to these coals. By his method the amount of fixed carbon as determined in the proximate analysis subtracted from the total carbon as determined in the ultimate analysis will give the amount of volatile carbon. His classification is based on the ratio of this volatile carbon to total carbon. In the above Meadow Branch mine coal the total carbon is 86.14 per cent., and the amount of fixed carbon is 81.37 per cent., so that the amount of volatile carbon would be 4.77 per cent. The ratio of the volatile carbon to total carbon would be 4.77 divided by 86.14, or 5 per cent. According to the table above of the Parr classification, this ratio falls in the semi-anthracite group and the Meadow Branch coal is not properly called anthracite, but it is a **semi-anthracite.**

The heating value of coal is expressed in terms of British Thermal Units. The British Thermal Unit, usually marked B. T. U., represents the number of pounds of water one pound of the fuel will raise one degree Fahrenheit. It is a convenient and scientific method of comparing heating values of different coals. The Pittsburgh Coal at Fairmont contains about 14,200 B. T. U., and it is regarded as one of the best steam coals. The highest value ever found in the coals of this State is 15,927 B. T. U. in the Pocahontas field. The heating value of this Meadow Branch mine semi-anthracite coal as determined in the Survey laboratory is 14,630 B. T. U., which shows it to be a coal of very high heating value.

CONCLUSION.—By the extreme folding and duplication of the coal seams on the overturned eastern limb of the syncline on Third Hill Mountain, and the nearly vertical position of the beds, and the fact that the outcrops here come to the surface, this has been the favorite locality for prospect work, and most of the openings have been made in this direction. These deceptive foldings and duplications seem to confirm this opinion of the prospectors as to the best place for work. He has thus determined that the coal seams are thicker in this portion of the syncline and therefore thinner in the valley and on the eastern slope of Sleepy Creek Mountain. By this close folding and resultant fracturing of the beds, there is an apparent increase in thickness in pockets at various places over Third Hill Mountain, but also the coal and slate are greatly crushed and so intermingled that it is almost impossible to separate coal from slate in any commercial quantity or at any reasonable cost. In this part of the area, the coal, as Campbell pointed out in this report, is in much poorer condition for mining and shipping than in the valley. Campbell advised in his report that "the commercial development of the field should be undertaken as near the center of the basin as it is possible to locate", for the very good reason as he states that "even a very casual examination of the Meadow Branch field will show that the rocks constituting the eastern or overturned limb are much more disturbed and fractured than those in the center of the basin. The coal, being the softest member involved, has suffered the greatest amount of disturbance and consequently it is reduced to the crushed condition shown in the Chappelle shaft."

These various reports made by coal engineers and geologists, from Rogers' report in 1838 to the present time, have shown that coal of the semi-anthracite variety is found in the Meadow Branch field in seams of probably 2 to 3½ feet thickness with local thickening to much greater amount. In selected samples free from the slate, it is of very high quality. It is, however, so intermingled with the slate and so badly crushed, that it is at the present time impossible to economically separate the coal from the slate into a commercial product. There is the added expense in this field of large quantities of water which involve a considerable charge for pumping, and there is no railroad to the field. The railroad is five miles distant and the route is favorable to construction. There would be no great difficulty in building a railroad to the field if the coal justified the investment.

With all this agreement on the part of various engineers who have reported on this field, yet Col. J. M. Guffey, a practical and successful operator for many years in the Pennsylvania and West Virginia coal fields, after an investigation of the proposition, came to the conclusion that these reports were not accurate as to the value of this coal as a commercial product in this territory, and he invested large sums of money in securing control of the entire field and in sinking shafts and inclines. He prosecuted this work with great activity with a working force in the field and an equipment of machinery for operation. He probably has done more in opening up the field than all that had been done before. His work was being pushed until business demanded all his attention in other fields, and the work here ceased about 1911. While rumors are afloat as to resumption of the work, nothing has been done since that time.

All of these surface openings are now caved in, and the shafts and inclines are full of water, so that no investigation can be made on the ground of the coal in these openings. Only the dumps are available for study and they do not furnish very satisfactory data. It is therefore impossible in this Chapter to give much additional data to that included in the papers of the engineers quoted in the preceding pages, who visited this area when the openings could be studied.

CHAPTER XIV.

THE LIMESTONE RESOURCES OF THE EASTERN PANHANDLE COUNTIES.

GENERAL DESCRIPTION OF THE LIMESTONES OF THE EASTERN PANHANDLE AREA.

In Berkeley and Jefferson Counties, West Virginia, occur vast deposits of limestone and dolomite which form the basis of a large quarry industry. This group of limestones of Cambrian and Ordovician age has for many years been known as the Shenandoah Limestone, and was named at an early date the Valley Limestone by Rogers, who pointed out its future value for the manufacture of hydraulic cement and agricultural lime.

The Shenandoah Limestone by later studies has been separated into a series of horizons as described in preceding Chapters on the Ordovician and Cambrian periods. It was there shown that one of the Ordovician limestones, the Stones River, contained limestone of very great purity, and this horizon furnishes one of the highest quality fluxing limestones in the country. Large quarries and plants are engaged in the work of furnishing this flux stone to the steel centers at Baltimore, Harrisburg, Johnstown, and the Pittsburgh district. It also furnishes a very pure lime, while the other limestones of the Shenandoah Group, more siliceous and magnesian in composition are quarried and used for lime, ballast, concrete, and road material. Beds of very low silica dolomite occur and are used to supply magnesian limestone for the basic furnaces of the Pittsburgh district.

The limestone and lime industries have become very

Martinsburg, and north to the deposits west of Falling Waters at Kunztown and at Indian Church on the Potomac. A second belt is opened at the Blair quarries three miles east of Martinsburg, thence trending north by Myers Bridge east of Opequon. The third belt is shown in the good limestone west of Whitings Neck, continuing north into Maryland near Williamsport Station, and southward to Van Clevesville. By folding these belts are duplicated in different parts of the area so there are a number of other short lines of outcrop often described as separate belts as they really are in outcrop. These different belts are not continuous on the surface, but dip down below the more impure rock for quite a distance, then come to the surface again.

In these belts are found a series of parallel high-grade ledges separated by other limestones, and they represent folds of the same stratum with the tops of the folds eroded away. This feature is well shown in the tracts south and east of Martinsburg. This parallel arrangement of high-grade ledges and the resulting large tonnage available are unique in the limestone fields of this country and render the district an ideal location for the quarry industry of high-grade flux limestone.

While the industry is about twenty years old, it is really in its infancy so far as development is concerned. There are as large and valuable deposits to-day on the market at reasonable prices as have already been opened by existing companies. It forms a promising field for profitable investments. Two steel companies now own tracts of this limestone but have not opened them. Another steel company is operating quarries, and another is making preparations to operate on a large scale.

Since not all the stone in this area is high-grade, it becomes very important in locating sites for plants to secure a sufficient acreage of the good stone. This involves very careful prospect work, followed by thorough testing of the formation. Prospect work seems to show that the low silica and low magnesian stone disappears a short distance north of the river in Maryland. It is a restricted area of about 25 miles in length by five miles in width, but with a very large tonnage, and is a valuable asset in the State's mineral wealth. From this district at the present time about 1,000,000 tons of flux are shipped annually. The district is reached by three railroads—the Baltimore and Ohio, the Cumberland Valley Division of the Pennsylvania System, and at the north by the Western Maryland.

In all the Martinsburg quarries, the surface outcrop is deeply channelled and the rock projects in pinnacles and knobs, the interspaces filled with red clay. The stripping must therefore be done by pick and shovel, and a stripped quarry has an exceedingly rough and irregular surface very difficult to walk across. The stone high in carbonate of lime is very readily eroded and subject to solution, while the more siliceous limestone weathers with comparatively smooth surface.

As a result of solution the fissures are formed often to considerable depth and the limestone abounds in caves and underground watercourses. Such a watercourse or underground stream from the Big Spring to the south of the Standard quarries south of Martinsburg falls into a sink-hole and apparently passes under the Standard quarries issuing in large springs in the town and formerly furnished the water-supply of Martinsburg. The deepest quarry of the Standard Company near the Charlestown road at a depth of 90 feet opened an underground water reservoir and in one night it flooded the quarry to a depth of 50 or 60 feet. Continual pumping with large pumps for weeks failed to lower the water any appreciable amount and the quarry was abandoned.

Large quantities of water are pumped from nearly all the quarries in the Martinsburg district and when the pumps are shut down for a few days they fill with water. With the advantage of cheap and reliable electric power, all the quarries are operated with it which is furnished by two companies, one at Martinsburg, and one at Winchester with its plant near Millville in Jefferson County. The power is generated by waterfall on the Potomac and the Shenandoah Rivers, and is brought on high-power transmission lines to all the quarries where it is stepped down to the voltage required. The quarries are directly connected with the Baltimore and Ohio or Cumberland Valley Railroads by switches, some of which are two miles and a half long.

An added factor in the economy of the Martinsburg district flux is the great number of empty coal cars moving westward from tide-water back to the Pennsylvania and West Virginia coal fields. It is a great advantage to the railroad to have these cars loaded for the West and they can thus give a low freight rate on limestone flux for the Johnstown and Pittsburgh districts. The distance from Martinsburg to Pittsburgh is 230 miles and the freight rate of 65 cents a ton is the same as from the Altoona district by the Pennsylvania System over a much shorter haul. Eastward the rate is higher, being the same to Baltimore as to Pittsburgh though the distance is only 100 miles. This locality therefore is assured of a very low freight rate West, and what is also very important an abundant supply of empty cars even when the car supply is insufficient in the coal fields.

The three railroads in this district enable the stone to be sent to a wide market and the very low silica makes the stone in demand at all the steel centers. Limestone flux is shipped from Martinsburg into Ohio as far as Canton and to Youngstown under freight rates of $1.40 and $1.20 per ton, the high quality of the stone overcoming the high freight rate. The limestone flux is sold at 50 to 55 cents a long ton at the quarry.

The nearness of the limestone area to the Cumberland coal fields, less than 100 miles, gives a low cost for fuel and prompt shipments. The high-grade steam coal is laid down at the quarries for $2.50 to $2.60 per long ton, but even then it is found cheaper to use electrical power as far as possible.

The vertical depth of this high-grade limestone is not known. The deepest quarry, so far, attained a depth of 90 feet and the rock was still good. Diamond drill borings have been made to a depth of 200 feet and still in the limestone which was low in silica to 160 feet. In some of these core drillings the samples for 120 to 150 feet averaged less than one per cent. silica, but below that depth the silica increased rapidly. There seems to be an increase in silica in the quarries and in the drill-holes as the rock is followed below the surface, but the rate of increase is not uniform. When the pitching ends of the folds or lenses are approached the depth of the good rock becomes shallow and at 40 to 60 feet the more siliceous rock is encountered. In some of these folds that have disappeared below the more impure rock, drilling shows its continuation below. In one place north of the exposed high-grade rock a hole was drilled 65 feet through low-grade rock and then entered the very high-grade stone. This feature lends encouragement for future work in mining such limestones below the surface. Limestone mines are now in successful operation in Pennsylvania and they have the advantage in enabling the quarrymen to work in all kinds of weather and avoid all stripping cost. At some future time this method will undoubtedly be used in portions of this field.

The stripping of these quarries involves the removal of any low-grade rock over the good stone, but is mainly confined to the removal of the surface red clay and soil resulting from the disintegration of the limestone. This clay cover will vary from a few inches to 20 to 30 feet in low places in the outcrop. On account of the uneven surface of the stone, this stripping must be done mainly with pick and shovel and carted away.

In the earlier part of the work scrapers can be used. The stripping costs about 30 to 35 cents a yard and will average about one and a half to two cents a ton of stone with depth of quarry of 50 feet. Experiments have been tried to strip with hydraulic power but the clay when wet is very pasty and forms balls that will not wash away. In fact this character of the red clay of this region makes it very troublesome to move in wet weather, but in dry weather it crumbles to a loose sand. It is also very troublesome in following the crevices down into the deeper parts of the quarry where it must be removed in quarry cars.

In most of the quarries the contract system of labor is used, the men receiving so much a truck-load of stone or dirt removed. Both native and foreign labor are used, and a good active truckman will earn about three dollars a day on this contract system. The stone is broken in the quarry to one-man size, that is, as large as a man can lift into the truck. Such size stone is in demand at some steel furnaces. The more usual demand is for eight-inch size stone, and for this purpose the one-man stone is hauled to the crusher and broken to the required size. It is very important that no clay is loaded with the stone as clay is an aluminum silicate and would thereby increase the silica in a car-load of stone, thus making a load of low silica limestone run high in silica. Most of the quarry contracts at the present time are made on a basis of one per cent. silica or less. The stone is loaded into open gondola or hopper cars holding 45 to 60 tons, and railroad weights usually control the settlements.

FURNACE FLUX.

The great demand for the Martinsburg Limestone is for furnace flux in the steel districts. In the smelting of iron ore and in the conversion of pig iron into steel in the open-hearth furnace, a Flux must be used to aid in the fusion and to remove the impurities. Crushed limestone has proved to be superior to all other materials for this purpose when economy of production is considered.

Iron ore as used to-day in the Pittsburgh district contains about 45 to 50 per cent. metallic iron, mixed with silica, alumina, phosphorus, etc., as impurities. The ore is practically infusible at any ordinary temperature, but when mixed with limestone in the blast-furnace is readily fused. The acid impurities of the ore unite with the basic lime and magnesia of the limestone forming a fused slag which is drawn off, leaving the metallic iron more or less free from its impurities, and in the form of pig iron.

If the limestone flux contains a considerable percentage of impurities in itself, the use of such impure stone adds to the burden of work in the furnace. The efficiency of the

PLATE XXIV.—Contact of Waynesboro and Elbrook Limestones One Mile East of Shepherdstown near Cement Mill.

limestone will be lowered in at least four important ways, as follows:

First, a portion of the lime will be required to neutralize the silica and alumina of the stone used, so that more pounds of impure limestone are required than of pure rock. This involves a greater cost of stone to the charge.

Second, the larger charge of limestone required involves the use of more fuel to melt the larger charge, and thus a higher fuel cost.

Third, there is involved a higher manufacturing cost through decreased output with the use of lower-grade limestone.

Fourth, the additional stone required involves a higher freight cost on the limestone per charge of furnace. There would also be an increased labor cost in handling the additional amount of material.

A limestone with over four per cent. silica is not desirable in the blast-furnace, while in the open-hearth steel furnace practically all contracts require that the silica shall run under one per cent. It requires 1,000 to 1,500 pounds of limestone flux to the ton of pig iron made in the Pittsburgh district. In this district alone, 2,656,811 gross tons of limestone flux were consumed in 1911; and the Pennsylvania and Maryland furnaces used that year 4,293,637 tons of limestone. Most of the Pennsylvania flux came from that State where, by less distance from the quarries, freight rates were lower than from the Martinsburg area, but this stone averaged about three per cent. silica. The important problem to solve is therefore the commercial value of a low silica limestone as compared with the higher silica stone.

Valuation Of Limestone As Furnace Flux.

In the determination of the real value of limestone as flux, it is necessary both to deduct the percentage of impurities it contains, and also the amount of lime base that is necessary to flux these impurities.

The important impurities to consider are silica and alumina, and to flux these elements an equal quantity of lime is required. In the limestone this lime is in the form of carbonate, and 1.8 units of lime carbonate would equal one unit of lime oxide. To estimate the actual value of the limestone as flux, there must be deducted from the total amount of lime and magnesian carbonates, (c_a), the amount of silica and alumina (A), and also 1.8 times this quantity of impurities to flux the same, or,

$$c_a = 100 - (A + 1.8\ A), \text{ or } c_a = 100 - 2.8\ A.$$

It has been stated above that the larger charge of impure limestone required involves a larger charge of coke fuel and also a higher manufacturing cost through decreased output. The effect of these factors on the determination of the commerçial value of the limestone has been reduced to formulæ by the Maryland Geological Survey in their report on limestones (Vol. VIII, p. 242).

This Survey found that from the average northern furnace practice, the fuel carbon consumption is about 0.13 pounds carbon per pound of slag to be melted, or 0.1456 short tons of coke to the long ton of slag. They determined the cost of coke required by the impurities in a long ton of limestone as follows:

C—represents the extra coke (short tons) required for one long ton of limestone.
P—is the price of coke per ton.
fc—is the per cent. of fixed carbon in the coke.
A—is the per cent. of silica and alumina in the limestone.

It has been shown that to flux A per cent. silica and alumina of the stone requires an equal amount of lime, so that the amount of slag thus formed would be 2A. Then from the above,

$$C = 2\ A \times \frac{0.1456}{fc} \text{ or } C = \frac{0.2912\ A}{fc}$$

In furnace practice 5 per cent. is added for finely divided and waste coke which would change the above furmula to

$$C = \frac{0.2912\ A + .0145}{fc} \text{ or, } C = \frac{.306\ A}{fc}$$

P representing the cost of coke per ton, the cost of the extra coke required by the impurities of a long ton of limestone would then be determined as,

$$C = \text{Cost of extra coke} = \frac{.306\ AP}{fc}$$

To determine the higher manufacturing cost through decreased output as worked out by the Maryland Survey (p. 243) by the combination of the factors of cost of coke, stone, and manufacturing, let

M—represent manufacturing cost per ton of iron on pure stone basis.
C—short tons coke to care for impurities in one long ton stone.
A—the percentage of silica and alumina in the limestone.
fc—the per cent. of fixed carbon in the coke.
ck—short tons of coke used per ton of iron on pure stone basis.
I—the increase in manufacturing cost per long ton of stone due to its impurities.
S—long tons pure stone needed per ton of iron.

The manufacturing cost per day being nearly constant, the cost per ton of iron would equal a constant divided by the output, or M=1/output. The output is found in practice to be inversely proportional to the coke consumption, so that M : ck and also M/S : ck/S.

If an impure limestone is used the manufacturing cost per ton is M/S + I, and the coke used per ton of stone is ck/S + C, or,

$$\frac{M}{S} : \frac{M}{S} + I :: \frac{ck}{S} : \frac{ck}{S} + C. \text{ or, } I = \frac{MC}{ck}$$

C—has above been found to equal .306 A/fc, so that we have

$$I = \frac{.306\ MA}{fc \times ck}$$

Now combining the three factors and formulæ:

I. **The relation of silica and alumina impurities.**

$$c_s = 100 - 2.8\ A, \quad \text{or,} \quad c_s = 1 - .028\ A.$$

II. **By increased coke consumption,**

$$C = \frac{.306\ AP}{fc}$$

III. **By higher manufacturing cost involved,**

$$I = \frac{.306\ MA}{fc \times ck}$$

a formula is derived for the determination of the value of an impure limestone in the blast-furnace. Let V represent the value of a pure limestone, and V′ the value of an impure limestone, then,

$$V' = V\ (1 - .028\ A) - \frac{.306\ AP}{fc} - \frac{.306\ MA}{fc \times ck},$$

which may be condensed into,

$$V' = V\ (1 - .028\ A) - \frac{.306\ A}{fc}\ (P - \frac{M}{ck}).$$

The average analyses of Connellsville coke give the fixed carbon as 86 per cent. (fc). The price per ton is about $3.00 (P), and in the Pittsburgh furnaces it requires about one ton of coke to one ton of iron (ck). The manufacturing cost per ton of iron is about $1.25 (M). Substituting these values in the above formula would give,

$$V' = V\ (1 - .028\ A\ ) - .306\ A \times 2.$$

To illustrate the application of this formula, the Tyrone Limestone contains about 3 per cent. silica and alumina, while the Martinsburg stone runs about 1 per cent. The one per cent. stone would have a value of,

$$V' = V\ (1 - .0028) - .0612, \text{ or } V\ (.9360).$$

The three per cent. limestone would have a value of,

$$V' = V\ (1 - .0084) - .1836, \text{ or, } V\ (.8080).$$

If a value of 60 cents a ton be placed on the pure limestone, then the difference in value of the above limestones would be,

.60 x .9360 — .60 x .8080, or 7.7 cents a ton in favor of the Martinsburg limestone.

The freight rates on the 3 per cent. silica stone to Pittsburgh and on the 1 per cent. limestone from Martinsburg are the same, 65 cents per long ton. A long ton of 3 per cent. silica stone would contain 67.2 pounds of silica, and a long ton of 1 per cent. silica stone would contain 22.4 pounds of silica. The weight of the lime carbonate in the stone is 1.6 times that of silica, but the factor of conversion of the carbonate of lime to the oxide is 1.7, so that the relative weights of lime oxide and silica may be taken as equal in the limestone.

The waste amount of weight due to both the silica and the lime carbonate necessary to flux this silica, in the 3 per cent. silica limestone would be 134.4 pounds to the long ton; and in the 1 per cent. silica stone, 44.8 pounds. The freight rate of 65 cents a ton (2240 pounds) would be .029 cents a pound. In the 3 per cent. silica stone, the freight on the waste portions of the limestone would be 3.9 cents a ton; and in the 1 per cent. silica stone, 1.3 cents a ton, or a difference in favor of the low silica limestone of 2.6 cents a ton.

The difference in actual working value of the low silica limestone and the higher silica stone as determined above was 7.7 cents a ton, and the saving in freight on the low silica stone is 2.6 cents, so that the Martinsburg one per cent. silica limestone is worth to the Pittsburgh blast-furnaces 10.3 cents a ton more than the Tyrone district 3 per cent. stone now so largely used in that iron district.

Many furnace managers pay little or no attention to the relative value of these limestones and regard a stone that can be bought for 40 cents a ton as 10 cents cheaper than one at 50 cents. Most of the larger furnaces now insist on quality in stone and demand a low silica. On basis of values the above figures show that if the 3 per cent. silica stone in Pennsylvania is bought at 50 cents a ton, the Martinsburg low silica stone is worth 60 cents.

The influence of magnesia in the limestone on its fluxing value is a disputed subject among iron engineers. It is claimed by some that it has little or no value in the removal of sulphur from the ore. It, however, has the same property as lime in combining with the silica of the ore but to slightly less degree. The proportion of magnesium carbonate in the limestones now used in the Pittsburgh district is so small that its effects need not be considered.

Limestone vs. Lime Oxide as Flux.

In this country it is almost the universal practice to use raw limestone rather than calcined stone. Theoretically the calcined rock would be better, but practical tests show but little advantage and many disadvantages. There appears to be no question that the use of raw stone involves a large fuel loss which is at present impossible to offset.

In the use of limestone the carbonic acid gas of the stone is expelled at full red heat, but at this temperature the gas acts on the coke, so that each pound of carbon in the limestone absorbs a pound of carbon from the coke and carries it off in the gases. If 1,500 pounds of limestone are used for a ton of pig iron, the stone will contain 180 pounds of carbon and will remove 180 pounds of carbon from the fuel, or about 220 pounds of coke.

Calcining the limestone before use in the furnace to avoid this loss of fuel has proved a failure, according to Campbell, because lime oxide has a greater affinity for carbonic acid at a temperature below red heat. The calcined limestone is charged into the furnace at a temperature below red heat in an atmosphere containing carbonic acid which is always present in the furnace. The limestone oxide takes again its content of this gas and is changed back to lime carbonate, the result being the same as though raw limestone had been used.

It is also found to be impossible to expel practically all the carbonic acid in calcining limestone. Campbell further states that in the American practice of furnace use, such a strong blast is employed that much of the finely divided calcined lime would be carried away with the gases, overcoming any advantage in fuel saving.

Open-Hearth Steel Limestone.

Until the year 1890 practically all the steel in this country was made by the Bessemer process. In 1890, two-thirds of the steel was made in Bessemer converters, and one-third by the open-hearth process; while in 1907, the distribution was half and half, and since that date most of the steel has been made in open-hearth furnaces.

The Bessemer converter is a steel vessel somewhat barrel-shaped and lined with refractory material to withstand the high temperature, the intense chemical action, and wear and tear of the operation. It is open at one end through which it is charged and discharged, while at the other end are numerous openings or tuyeres through which passes the strong air-blast. Their capacity ranges from 5 to 20 tons, and no limestone is used in the process.

The Open-Hearth Process, according to Campbell, refers to the melting of pig iron with more or less wrought iron, steel, or similar iron scrap, and limestone, by exposure on a **hearth** to the direct action of the flame in a regenerative gas furnace, and converting the resultant bath into steel, the operation being so conducted that the final product is entirely fluid.

According to Stoughton, the standard size of open-hearth furnace holds 50 tons, and such a furnace has an inside length of 30 to 35 feet, width of 12 to 15 feet, and maximum depth of 2 feet.

In the acid open-hearth furnace the lining of the hearth is a silica brick, and can not be used where the charge contains sulphur or phosphorus as these impurities would not be removed. About one million tons of acid open-hearth steel is made in this country as compared with about 16 million tons of basic open-hearth steel.

In the basic open-hearth furnace, the lining of the hearth is dolomite (magnesium limestone), magnesite, or other basic material, and most furnaces use the dolomite. Like the acid process, the iron is melted and the silicon and carbon oxidized and partially removed, but the basic process in addition removes the sulphur and phosphorus by use of lime or limestone which is added to the charge.

The use of limestone, according to Campbell, has an advantage over lime, in the carbonic dioxide gas bubbling up through the mass, thus keeping up a motion favorable to chemical action, and also the carbonic dioxide aids in the oxidation of the phosphorus, carbon, silicon, and iron. The phosphorus unites with the lime, forming phosphate which enters the slag and is so removed. It requires in this process 180 to 200 pounds of high-grade limestone to the ton of steel, and the stone is preferred under one per cent. silica. In 1911 there were produced in the territory reached from Martinsburg under reasonable freight rate, 8,369,050 tons of open-hearth steel, which would require nearly 840,000 tons of high-grade limestone. Specifications for open-hearth steel limestone usually call for 1 per cent. or less silica, not over 4 per cent. magnesia, and alumina under 2 per cent.

High-Grade Limestone Supply.

It has been shown that low silica and low magnesia limestone is essential in the manufacture of open-hearth steel, and that it is superior to high silica stone in the blast-furnace economy. The following table from the records of the American Iron and Steel Association shows the consumption of gross tons of limestone in 1911 in the territory that can be reached under permissible freight rates from Martinsburg:

	Blast-Furnace.	Open-Hearth.
Allegheny County (Pittsburgh)...	2,656,811	498,400
Shenango Valley.................	643,779	41,947
Western Pennsylvania............	670,142	181,962
Harrisburg, Baltimore, Wheeling..	322,905	73,626
Mahoning Valley (Youngstown, etc.)	....	41,326
	4,293,637	837,261

A total consumption in 1911 of 5,130,898 long tons of limestone. The only source of the low silica stone for this territory outside of the small Annville, Pennsylvania, quarry and the larger Bellefonte quarry, is the Martinsburg district. Most of the blast-furnace stone now used in the Pennsylvania districts comes from the Tyrone area, where it has the following composition as compared with that at New Castle, Pa., and the Martinsburg limestone:

	Tyrone.	New Castle.	Martinsburg
Lime oxide	50.0	53.22	54.50
Magnesium oxide	2.0	0.61	0.85
Iron oxide	0.44	0.64	0.72
Alumina oxide			0.13
Phosphorus	0.007	0.025	0.005
SILICA	3.82	2.50	0.75

In the crushing of limestone for furnace flux, and screening to proper size, there is left a certain percentage of smaller sizes or screenings which by proper treatment have double or even triple the value per ton for certain purposes, over the fluxing stone. Especially is this true in the case of low silica limestone. The resultant by-products will be described in the following paragraphs.

GLASS MANUFACTURE.

Glass is made from a fused mixture of lime, sand or silica, and sodium carbonate (soda-ash); or in window- and bottle-glass, the carbonate is replaced by sodium sulphate (salt-cake).

Lime is used in most plants in the form of finely ground limestone, but a number of companies use the burned limestone or lime oxide, or the lime hydrate. The oxide and hydrate of lime absorb water or carbonic dioxide or both from the air, changing in composition and weight, which is very apt to give trouble in mixing in correct and uniform proportions. For these reasons most plants now prefer the unburned limestone.

The limestone for glass manufacture must be as nearly pure as possible. Any iron impurity has a tendency to color the glass green or brown, objectionable where a clear color is required. Magnesia tends to make the mixture more infusible. The limestone should run under one-half of one per cent. iron.

The following analysis shows the composition of the limestone used in the Pittsburgh plate glass manufacture:

	Per cent.
Lime carbonate	97.23
Magnesium oxide	1.48
Iron oxide	0.16
Alumina oxide	0.02
Silica	1.01

In the manufacture of window-glass in a mixture of 100 pounds of sand, 36 pounds of salt-cake are used and 36 pounds of lime oxide, or if crushed limestone is used, 65 pounds.

Available Market for Glass Limestone.

The glass works of West Virginia are located in the gas belt of the State with large plants at Grafton, Moundsville, Wheeling, Clarksburg, Weston, Buckhannon, Fairmont, Morgantown, Salem, Parkersburg, and other cities and towns. One of the great centers is in the Pittsburgh district, while other plants are located at Cumberland and Baltimore.

No accurate statistics are available as to the amount of lime and limestone used in these glass plants, but it is possible to approximate this demand in another way. West Virginia produces about 240,000 tons of glass-sand shipped to the different plants. It is reasonable to infer that freight rates would permit the Martinsburg limestone to be shipped to points where this sand is used, especially as most of this sand comes from Berkeley Springs in the adjoining county. The glass works use a little over half as much limestone as sand in their manufacture, so there would be a demand for at least 125,000 tons of limestone a year. In addition, Pennsylvania glass works can be reached which are supplied with Pennsylvania glass-sand. The glass-sand production in that State is about 440,000 tons a year. The demand for limestone at glass plants within the possible freight shipping territory of Martinsburg can not be far from 250,000 tons a year. The selling price of this limestone crushed to about the size of fine gravel or coarse sand for glass manufacture has been for some years $1.25 a ton on board cars in Martinsburg. This glass limestone is loaded in bulk in box cars.

ASPHALT PAVING.

A considerable quantity of limestone crushed to pass a 100-mesh screen, or in the form of a fine flour is used in the surface coat of asphalt pavements. It requires about 105 pounds of this flour to 22 square feet of paving. This material is shipped in sacks and sold at the mill for $2.00 a ton plus the cost of sacks which is refunded on return of bags in good condition. During the paving season in Washington City, the Cranford Paving Company, a division of the Barber Asphalt Company, used about 25 tons a month. The Brennan Paving Company used about 50 tons a month, and their material comes from Martinsburg as does that used by the Cranford Company.

INGREDIENT IN COMMERCIAL FERTILIZERS.

In and near Baltimore, there are 35 fertilizer plants, and probably twelve of these manufacture commercial fertilizers, the others being distributing plants. Limestone crushed to pass a 50-mesh screen and loaded direct in box cars is used at these plants to a small extent as a filler. A large amount is used in the process of manufacture of these fertilizers from phosphate rock. Phosphate rock as it comes from the southern mines is insoluble and if spread over the land would be of little or no benefit because it does not go into solution and the phosphorus would not be available for plant food. This insoluble rock phosphate at the fertilizer works is treated with sulphuric acid whereby it is converted into the super-phosphate, a soluble compound. The excess of acid in this product would be injurious to growing vegetation and must be removed at the works. This is done by adding ground limestone which takes up the acid forming a lime sulphate. The limestone used should be as nearly pure as possible and should be especially low in iron and silica. The Martinsburg limestone has a high reputation for this work. The total demand in the Baltimore market is about 8,000 tons a year and it is sold at Baltimore for $2.25 a ton. The freight rate from Martinsburg to Baltimore is 60 cents, making the net price at the quarry $1.65 a ton.

Minor uses of ground limestone are in manufacture of carbonic acid gas used in charging soda water, mineral waters, etc. Also it is used in the manufacture of soda-ash by the Solvay process, and in the manufacture of certain chemicals.

LIMESTONE FOR LAND FERTILIZER.

Lime and limestone are used on farm lands not to furnish direct food for plants, but on account of the physical and chemical effects on the soils. They have a very important physical effect on the texture of soils in two opposite ways. By their use on a stiff compact clay soil, it is made more open in texture; while on an open loose soil, as in sandy soils, the lime or limestone causes a gathering together or flocculation of the soil particles, rendering the soil more compact.

The great value of this material, however, is in the chemical action on worn-out lands, or on soils which have decreased in fertility. Soils long used without fertilizer or where too much acid phosphate fertilizers have been used, become acid in reaction, or are termed "sour lands". The lime or limestone counteracts this condition. In past years lime was used, but investigations by agricultural chemists in the various State Experimental Stations show that limestone is equally good if not better. It requires more limestone per acre than lime, but the price being lower, the cost is no greater. It is also found that the lime in many cases is injurious to the small rootlets of growing plants through its burning or caustic energy.

The use of limestone as a fertilizer is rapidly increasing in many States, like Ohio, Illinois, Maryland, and a number of the southern States. In West Virginia up to the past few years not much lime has been used as fertilizer except near a few lime centers, but now the use is increasing. Not many farmers as yet use the ground limestone and the State Experiment Station appears to advocate the use of lime rather than limestone. The experience in other States seems to be in favor of the limestone. Many of the soils of this State are found on chemical examination to be acid, and the farmers are beginning to appreciate the value of lime fertilizer. Small plants back in the country have been unable to supply the local demand.

In equivalent value on soils 500 pounds of ground lime are equal to 950 pounds of lime hydrate, or to 1,200 pounds of ground limestone. This is the quantity used per acre on moderately acid soils. The West Virginia Experiment Station recommends for acid soils in this State 1,500 to 2,000 pounds of burnt lime to the acre, or 3,000 to 4,000 pounds of ground limestone.

As to the value and results of the use of limestone on soils, the University of Illinois Experiment Station found on sixteen trials using a mixture of one ton of rock phosphate fertilizer and two tons of ground limestone to the acre, there was an increase in hay from 1.7 to 2.87 tons per acre or an average increase of 65 per cent. On six fields of grain, the increase was 1.25 tons. As soon as the farmers in this State realize that such increase in crops is possible by the use of ground limestone, there will be a large market open for this product. For this use, the limestone is ground to the size of coarse corn meal and is sold at the plant at $1.00 to $1.25 a ton.

Limestone in a pulverized condition is acted upon by nitric acid formed by decaying vegetable matter, and produces lime nitrate. The nitrogen so essential to plant growth is thus preserved in the soil and given up slowly to the growing plants. Limestone also aids in the formation of the brown humus or vegetable matter found in all fertile soils. In these two respects it is far superior to the burned lime.

Freight Rates on Ground Limestone.

The following rates for freight per ton (2240 pounds) apply on ground limestone from Martinsburg to the following points:

Baltimore, Md.	$0.60	Morgantown, W. Va.	$1.20
Buckhannon, W. Va.	1.50	Parkersburg, W. Va.	1.50
Clarksburg, W. Va.	1.20	Philadelphia, Pa.	0.75
Cumberland, Md.	0.60	Pittsburgh, Pa.	1.20
Curtis Bay, Md.	0.60	Uniontown, Pa.	1.20
Myersdale, Pa.	1.00	Washington, D. C.	0.60
Newark, Del.	0.75	Wheeling, W. Va.	1.50

Shipments of ground limestone are now made from Martinsburg to all of these places, and they may be considered as within the possible freight shipping territory. The above cities are selected to show the range of this possible territory.

DOLOMITE.

A dolomite is a magnesian limestone in which a greater or smaller amount of lime carbonate is replaced by magnesium carbonate. A typical dolomite contains 54.3 per cent. lime carbonate and 45.7 per cent. magnesium carbonate. Limestones which contain 30 per cent. or more magnesium carbonate are usually termed dolomites, though it would be more correct to call such rocks dolomitic limestones. Limestones with less than 30 per cent. magnesium carbonate and over 8 to 10 per cent. are called magnesian limestones.

Uses of Dolomites.—In the basic Bessemer and the basic open-hearth steel furnaces, the bottom of the furnace must be basic, and it is made usually of dolomite or magnesian limestone. While the dolomite rock is sometimes used in its natural state, it is regarded as better practice to calcine the stone, grind it, and then mix with coal tar. In the basic Bessemer process the vessel is lined with this mixture. The dolomite should be low in silica and carry a high percentage of magnesia.

Magnesian limestones are burned into lime which has the properties of slow setting, and generate a low temperature on hydration. They are also available for ballast and for road material.

For certain furnace processes a double-roasted dolomite is required. The stone is burned at high temperature in the ordinary kilns and then burned to a clinker in a rotary kiln. In this area, the clinkered dolomite is produced by very high temperature in ordinary kilns, which is a difficult operation on account of the fire-brick linings fusing more or less under the high temperature required. This double-roasted dolomite is now produced near Millville at the Blair plant, and at Martinsburg at the Standard kilns from dolomite shipped from Millville.

Dolomites and dolomitic limestones are wide-spread and are found in many localities, but low silica dolomites are limited, and one of the most important deposits in the country is found in Jefferson County, where dolomites of almost theoretical purity occur around Millville and are there extensively quarried. The composition of these Millville dolomites is shown in the following analyses made in the Survey laboratory, except those from the Blair quarry:

	Standard Quarry. 1905		Harpers Ferry Lime Co.		Theoretical Composition.
Lime carbonate	55.72	55.00	55.00	54.00	54.30
Magnesium carbonate	43.18	45.00	45.00	46.00	45.70
Iron and alumina	0.89	0.41	0.57	0.47	
Silica	0.05	0.40	0.30	0.30	
Sulphur	none	none	none	none	
Phosphorus	0.01				

In 1915, a number of samples were again taken from these quarries and from an old abandoned quarry to the east with the following results on analysis in the Survey laboratory:

	Quarry to east		Baker, old quarry.		Baker, working quarries.		
	193	194	195	196	197	198	199
Lime carbonate	78.00	83.30	53.56	54.08	54.43	54.29	54.11
Magnesium carbonate	7.93	11.36	43.89	45.03	44.26	44.69	43.96
Iron and alumina	2.60	1.31	0.89	0.33	0.61	0.45	0.40
Silica	9.60	3.96	1.05	0.48	0.43	0.38	0.53

No. 193 is from the east wall of this old quarry and 194 from west wall. No. 195 is from the east wall of the old quarry of the Standard Limestone Company and No. 196 at the north end of this quarry. No. 197 is in the next quarry north which was not worked in 1915. No. 198 is from the deepest ledges yet worked and where a large portion of the 1915 output was obtained. No. 199 is at the extreme north end of the quarry openings and on the west wall.

The Blair dolomite quarry is west of Millville and one mile west of the above quarries of the Standard Company. The composition of the dolomite is shown by the following analyses:

Lime carbonate	54.32	54.33	53.92	53.72	54.40
Magnesium carbonate	44.48	45.16	44.60	45.35	45.75
Iron and alumina	0.94	0.60	1.14	0.90	0.16
Silica	0.82	0.32	0.60	0.40	0.16

The analyses show the high quality of the Millville dolomites with their exceptionally low silica percentage. There appear to be two main belts of dolomite, one to the east of Millville which includes the quarries of the Standard Lime and Stone Company, and the Harpers Ferry Lime Company, across the river; and one to the west of Millville, at the Blair quarry, which can not be traced very far to the north or south.

The east belt extends south to the Harpers Ferry Lime quarry and north to the Potomac River. Two and a fourth miles north of the Standard quarries at Millville, the dolomite belt is 300 to 325 feet wide. Samples were taken at this place and showed the same low silica dolomite. The third sample was taken near the edge of the belt where silica increases in amount.

Analyses of Dolomite near Dupuy Mill on the Potomac.

Lime carbonate	54.90	54.28	53.82
Magnesium carbonate	44.57	44.25	41.88
Iron and alumina	0.35	0.79	1.64
Silica	0.18	0.68	2.66

PLATE XXV.—Semi-Anthracite Coal Mine near Top of Short Mountain on Meadow Branch.

A belt of dolomite extends south of Millville to the Keys Ferry road on and near the Wetzel farm. The dolomites were sampled and analyzed in the Survey laboratory, as follows:

	D-1.	D-2.	D-3.	D-4.	D-5.	D-6.
Lime carbonate	53.78	66.53	54.70	55.20	54.27	55.63
Magnesium carbonate	42.63	31.77	43.58	43.47	44.00	43.36
Iron and alumina	1.39	0.55	0.90	0.60	0.66	0.42
Silica	0.27	0.30	0.61	0.46	1.01	0.30
	D-7.	D-8.	D-9.	D-10.	D-11.	D-12.
Lime carbonate	53.98	63.39	53.68	63.02	61.94	54.00
Magnesium carbonate	44.10	34.83	41.13	32.29	32.73	44.27
Iron and alumina	0.33	0.54	2.34	1.55	0.70	0.90
Silica	0.60	0.78	2.23	2.95	3.72	0.76
	D-13.	D-14.	D-15.	D-16.	D-17.	D-18
Lime carbonate	53.84	55.34	55.20	53.30	62.95	54.38
Magnesium carbonate	43.19	43.58	43.00	43.50	36.14	44.72
Iron and alumina	0.33	0.70	0.55	0.26	0.29	0.60
Silica	2.54	0.37	0.81	3.04	0.54	0.68
	D-19.	D-20.	D-21.	D-22.	D-23.	D-24.
Lime carbonate	54.48	55.41	57.50	61.24	61.52	57.41
Magnesium carbonate	40.72	42.33	41.42	34.36	35.32	40.46
Iron and alumina	3.35	1.80	0.66	0.85	0.38	0.35
Silica	1.08	1.02	0.35	2.24	1.45	1.11

The above samples were taken over an area of one-fourth to one-half mile west of the river and over a length of a half mile north and south. The higher silica dolomites (9, 10, 11, 13 and 16) were on the east side of the low silica belt, while samples 22, 23 and 24 were taken near road to Halltown, three-fourths mile north of Keys Ferry road.

Dolomites are found through the Beekmantown Limestone Formation, but run high in silica. They would be available for the manufacture of magnesian limes. They are usually bluish-gray in color, and in some ledges grayish-white, having a granular surface on fracture.

The following analyses are of Beekmantown dolomites from the National Limestone Company's lands south of Martinsburg near the plant (181) and southeast of plant (A and B). No. 10 is from the small quarry on the Potomac River west of the Pittsburgh Limestone Company's quarries. Nos. 167 and 168 are from the area east of Opequon between the two low silica limestone belts on the Blair property:

	A	B	No. 10	No. 167	No. 168	No. 181
Lime carbonate	53.53	52.64	60.44	59.36	58.47	52.32
Magnesium carbonate	35.82	41.71	37.60	36.08	37.50	40.42
Iron and alumina	1.30	1.25	0.18	0.91	0.92	1.35
Silica	5.90	3.90	1.83	4.43	3.85	5.63

Stones River Dolomites.

Below the low silica ledges of the Stones River, in the Middle and Lower divisions of this formation, are dolomites with a high percentage of magnesium carbonate, but they are usually high in silica. The change in the strata from the low silica limestone to the higher magnesian rock is quite sharp, and the line between them can be drawn readily in the field. To illustrate the change between the Lower and Middle Stones River, two analyses are given below, one (No. 4) is of a sample taken just above this line, and the other (No. 5), came from below the line. The two samples were taken about six feet apart at the eastern end of the Pittsburgh Limestone Company's quarry.

Analysis No. 3 is of a dolomite ledge 15 feet below this line, while No. 6 sample was taken 75 feet below this line and shows a considerable increase in silica. These dolomites vary in silica in the different ledges, and it would require most careful selection to secure low silica stone in any quantity:

	No. 4.	No. 5.	No. 3.	No. 6.
Lime carbonate	98.25	58.65	59.85	52.44
Magnesium carbonate	0.77	37.67	38.23	39.87
Iron and alumina	trace	1.05	0.52	0.53
Silica	1.10	2.50	1.53	6.98
	100.12	99.87	100.13	99.82

The mixture of these dolomites would probably make a very good grade of magnesian lime which would be slow setting, and should make a hydrate that would compete with the Ohio magnesian lime hydrate now so popular in the eastern markets. Nearly all the dolomites in the Martinsburg district are too high in silica for use in the basic steel manufacture, but here and there occur ledges comparatively low in silica like the above. These dolomites are less valuable than those of Millville, where the silica is under one per cent. The dolomites are found in both the Lower and Middle divisions of the Stones River, but no use is made of them at the present time.

Origin of Dolomite.

The origin of these highly magnesian limestones has been a subject of investigation and study for a very long time and various theories have been advanced. One of the first theories advanced was that the dolomite was formed from magnesian vapors that escaped from the interior of the earth through fissures, but this theory has long been abandoned.

A second theory has been advanced by some very able scientists of modern times, which regards magnesian rocks as chemical precipitates from old oceans, the lime and magnesia being deposited at the same time, forming the double compound of lime and magnesium carbonates. Bischof by experiments with saturated solutions of lime and magnesia found that the lime carbonate was largely precipitated before any quantity of the magnesium carbonate was thrown down, so the natural order would be separate layers of lime and magnesium carbonates rather than a mixture of the two.

The third and generally accepted theory of origin of magnesian limestones is that of replacement of the lime carbonate by the magnesium carbonate particle by particle. This change may have taken place in the original sediments, or after these sediments were consolidated into rock.

A fourth theory is that certain kinds of marine animals and plants secrete magnesium carbonate in large quantities, and their remains probably formed the source of the dolomites.

Blackwelder (Bull. Geol. Soc. Amer., Vol. 24, p. 624) has suggested that the dolomites owe their origin to "the almost simultaneous interaction of the bottom layers of sea water charged with magnesian salts, on shells, skeletons, and other particles of calcite and aragonite, accumulating as loose sediments on the sea-floor." In other words, the replacement took place in the sediments before their consolidation into solid rock.

Daly (Bull. Geol. Soc. Amer., Vol. 20, pp. 153-170) from a study of a large number of analyses of limestones found a close agreement in the ratio of lime to magnesium in the pre-Devonian limestones with the ratio of these elements in typical modern rivers and reached the conclusion, "that all the pre-Devonian river-borne calcium and magnesium were precipitated on the sea-floor. The ultimate products are dolomites and magnesian limestones as well as more purely calcareous limestones."

Daly further found that the lime—magnesium ratio increases from an average of 3.35 to 1 in the pre-Devonian to 6.29 to 1 in the Devonian limestones. In the Carboniferous the ratio is 12.45 to 1, and in the Cretaceous 56.32 to 1. There is thus a marked increase in lime content and decrease in magnesia from the earlier formation to the later. The ratio in 44 existing rivers he found to be 4.18 to 1 and in the Mississippi River is 3.92 to 1, a very close agreement with the pre-Devonian ratios.

These results are very suggestive when compared with the composition of the Cambro-Silurian Limestones of Berkeley and Jefferson Counties. Here the lower formations are highly magnesian often pure dolomites, while above come less magnesian limestones until the Stones River exceptionally pure carbonate rock is reached. This relation would suggest that in the old ocean in which the lime sediments were accumulating the magnesium was deposited along with the lime, resulting in a decreasing supply of magnesia until it was practically absent.

Overlying the Stones River, the Chambersburg Limestone again contains a higher content of magnesia, but it is also higher in alumina and is followed by the clay shales of the Martinsburg division, indicating an influx of muddy sediments through rivers from near-by land areas and a renewed supply of chemical elements.

This method of origin should result in a gradual decrease in magnesia as the geological divisions of the Cambro-Silurian are followed upward. The same stratum formed at the same time would be fairly uniform in its percentage of magnesia, which is not the case. A given stratum varies greatly in its composition as followed from section to section.

Origin of the West Virginia Dolomites.

In Volume III of the West Virginia Geological Survey, the writer outlined a theory to explain the origin of the dolomites in the eastern Panhandle area which seems to account for the present distribution of the rocks, and which is here reprinted.

In these counties both high calcium limestones and dolomites are found in belts trending northeast-southwest and which are usually highly tilted. The lines of contact of the two grades of rock are sharp, often with no gradation of magnesia from one to the other, while in a few places the two kinds of rock are separated by a belt of lower-grade limestone containing 10 to 15 per cent. magnesia. The dolomites are compact instead of porous in texture, and the purest limestone appears to follow closely the shale contact.

The geological history of the area may be stated briefly as follows: The lime sediment was deposited on the floor of the old Cambrian and Silurian oceans, and later covered by the mud in the Silurian sea, now represented by the Martinsburg Shales. The whole mass of sediment was raised into land and consolidated into rock. The rocks were thrown into a series of folds broken and faulted by crustal movements that took place during the Paleozoic division of geological time and culminated at its close. During all the long time since their upheaval into a land area, these rocks have been greatly eroded, the tops of the folds are gone, leaving the highly tilted rocks with shale masses here and there.

At some time in this history there was a partial replacement of the lime carbonate by magnesium carbonate in the limestone. Not all the rock was changed, and in some parts of the formation the replacement was more complete than in other portions. This change must have taken place before the sediments were raised from the sea, or after the rocks formed part of the land area. Above, some reasons have been given against the theory that this change took place in the sediments before their consolidation.

Over the limestone is now found the remnant of the Silurian muddy sediments in the Martinsburg Shales, over 700 feet in thickness. These mud sediments represented a great change in the physical condition of the old Silurian sea. The floor was probably sinking slowly, with shallow-water conditions and an inflow of salt-laden waters from the land area. If at this time the limestone sediments were replaced in part by the magnesium carbonate to a certain depth, there would be magnesian rocks on top with purer limestones below. When the rocks were later folded and eroded, the magnesian layers on the top of a single fold would form two belts separated by the higher calcium ledges, and the arrangement would be repeated in the next fold. The upper ledges would be next to the overlying shales, but there are found the high calcium rocks.

The explanation that there was in the Silurian sea a series of elongated enclosed basins where evaporation was greater and conditions especially favorable for the replacement of lime by magnesia would necessitate, for this area, the assumption that there was a large number of parallel basins, 50 to 100 feet wide and lenticular in form, which does not seem probable. There seems to be little support for any theory of replacement of the lime by magnesia in these sediments while under the sea.

Assuming that the change took place later, the replacement occurred in the long time before the mountain uplift, during the uplift, or afterward.

In the earlier history of these rocks before the mountain uplift, the limestones were covered with shales of very considerable thickness and very compact, so that downward-circulating waters would have little effect on the covered limestones. It is doubtful if this mantle of shales was removed during the Paleozoic time, and if so in places, the alteration would be found only in the surface layers.

If the replacement has taken place wholly since the uplift, it is difficult to explain the occurrence of the dolomite in certain belts, and with the sharp lines of contact with pure limestone in areas where both rocks would be brought equally under the influence of the circulating waters. Further, under normal conditions of pressure, limestones are never changed to pure dolomites. Great pressure or long-continued lower pressure would be necessary to cause any complete replacement of lime by magnesia to form a true dolomite. The dolomites thus formed would be more or less porous and show caves and open fissures due to the solution effects, but these dolomites are very compact.

During Paleozoic time there were crustal movements' folding and faulting the great series of accumulated sedimentary rocks, movements that reached their culmination at the close of that period or at the close of the Coal Measure Group. The replacement of lime carbonate by magnesium carbonate in the true dolomites results in a diminution of bulk of 12.3 per cent. With increased pressure, this change would be more complete, if the solutions were available. The dolomites of this area of the State do have nearly the theoretical proportions of lime and magnesium carbonates. The crumpling and resultant fracturing of the rocks would give better access to circulating waters especially along the lines of fractures and faults.

According to Van Hise (U. S. G. S., Mono. 47, p. 798, ff.), limestones, in regions of strong mountain movements with the consequent fracturing, are more strongly magnesian than limestones of the same age in less disturbed regions. He therefore reaches the conclusion that limestones are apt to be magnesian in proportion as there were favorable conditions for the entrance of solutions bearing magnesia.

Near Shepherdstown where the rocks are highly tilted and crumpled, nearly all the limestone is magnesian. The Shenandoah Limestones near the fault-planes east of Charlestown are very highly magnesian. Where the rock folds are broad and not so much broken over the area of the two counties of the eastern Panhandle, the limestone is low in magnesia, the carbonate seldom reaching ten or twelve per cent. At Cedar Cliff in Mineral County, where there is similar folding and crumpling, the limestone of Helderberg age is highly magnesian but not a true dolomite. Under such conditions there must have been great pressure on the rocks and channels opened for circulating waters.

Near the shale contact, even with high tilting and apparently similar conditions to those outlined above, the rock is an exceptionally pure limestone with less than one per cent. of magnesia. In such areas, the overlying compact shales have doubtless protected the rock from the magnesia-bearing solutions, and the rock may have been rendered so compact by the pressure that the solutions could not readily pass into the limestone.

The Martinsburg Shales contain an average of 2.65 per cent. of magnesium oxide, but the decomposed and weathered surface shales contain only 1.2 per cent. Downward-circulating waters would have magnesia in solution derived in part from the shales, and in part from other rocks more or less distant from the limestone area. According to Van Hise, it is a chemical law that solid lime carbonate in contact with a solution containing lime and magnesia will have part of the lime replaced by magnesia, and the interchange will take place more rapidly where the percentage of magnesia is low in the rock, but the reaction will be very slow in highly magnesian limestone except under the influence of pressure.

Whether the magnesian solutions in this area came from above or below is difficult to determine from the evidence at hand. There appears to be no metal deposition and no evidence of heated water. While upward-circulating waters may have been present, their presence would not seem to be required to explain the replacement.

As a summary of the above discussion, the origin of the eastern West Virginia Cambro-Silurian dolomites and magnesian limestones is regarded by the writer as due to the replacement of lime carbonate in part by magnesium carbonate brought in solution into downward-circulating waters, a reaction which took place in the rocks after they were consolidated and at the time of their folding and faulting probably near and at the close of the Paleozoic era of geological time.

MARL DEPOSITS.

Marl is a soft earthy lime carbonate, and represents a lime sediment unconsolidated. It varies in texture from a crumbly or incoherent powdery mass to a more or less solid earthy stratum. It is found in lakes, swamps, or stream valleys in many parts of the country, and varies in thickness from a few inches to 40 or 50 feet.

Marl forms the basis of the Portland cement industry in Michigan[1] where it has the following composition:

	Light Marl.	Blue Marl.
Lime carbonate	93.75	91.34
Magnesium carbonate	2.42	0.77
Silica	1.19	1.20
Alumina oxide	0.55	0.55
Ferric iron oxide	0.25	0.40
Alkalies, organic matter	1.84	5.79

Marls are often described as impure carbonate of lime deposits associated with high percentage of clay, but the Michigan marls and those in eastern West Virginia are quite free from impurities. They are found in a number of places in the eastern Panhandle area. There are large deposits near Millville, and east of Charlestown in Jefferson County, near Bunker Hill, south of Martinsburg, and many other places. In fact this marl is found in practically every stream valley within the limestone area, but many of such deposits are very limited in extent. It requires careful prospect work to determine whether these local deposits would justify development. Some of the deposits are known to cover a broad area and with good depth. One near Millville is 15 feet thick in the run bank and probably is much deeper, containing 92 per cent. carbonate of lime, as exhibited below:

[1]Michigan Geological Survey, Vol. VIII, p. 247.

	Wetzel	Farm.
Lime carbonate	92.26	90.16
Magnesium carbonate	1.54	1.30
Silica	1.80	2.18
Alumina	1.23	4.41
Iron	1.23	
Titanium	0.06	

The marl deposits are found along stream valleys in this area in the limestone country, and they are probably due to surface waters leaching the adjoining limestone. The circulating waters carrying the lime carbonate in solution flow to lower levels in the stream valley where their current is checked and the waters spread out over a wider area and by evaporation deposit the lime in layers as bog lime or marl.

As pointed out by Davis in the Michigan Geological Survey Report (Vol. VIII, pp. 65-96) vegetable algæ have the property of extracting carbonic acid gas from the water, resulting in the deposition of the lime salts in their cellular structure and on their surfaces. Algæ are found in nearly all these runs and they probably have aided in the formation of these marl beds and possibly have formed the greater portion of the deposit.

In the southeastern corner of Jefferson County along Long Marsh Run from Rippon to the Shenandoah River are deposits of purplish-gray marl of which six to eight feet are exposed in the banks of the run. The valley is narrow but appears to be all covered with marl well shown a mile and three-fourths southeast of Rippon at the cross-roads and near the Kabletown Pike.

Further north along Bullskin Run from east of Summit Point past Wheatland and Kabletown to the river show extensive marl deposits. They cover a broad area on each side of the Norfolk and Western Railroad at Wheatland. The composition just east of the railroad is shown by the analysis, No. 100. Sections show that it is 20 feet deep along the run and it covers the valley here. It extends up the run past the cross-roads over a mile west of the railroad.

Evitts Run is lined on both banks with marl deposits. Its composition one mile southwest of Bloomery near the old mill is given in analysis No. 168. Near the east edge of Charlestown, close to both the Norfolk and Western and Baltimore and Ohio Railroads on this run, there is a broad area of the marl which also extends northwest up the run. Its composition at the edge of town is shown by analysis No. 176. The composition of the marl along Cattail Run, three-fourths mile from its mouth, is given in analysis "A" from Wetzel Farm. where 20 feet are exposed.

Turkey Run through Middleway is bordered by good deposits of marl. All along Flowing Springs Run from north of Charlestown east past Halltown, the marl beds are clearly seen and cover a wide area west of Halltown. One mile west of this town, just north of the railroad and east of the county road, the marl composition is shown by No. 173. Nearly all these Jefferson County runs show more or less marl.

In Berkeley County, there are large deposits along Mill Creek at Bunker Hill associated with blocks of harder travertine. Its composition is given by analysis "B". These deposits are seen near Gerrardstown on the same run. South of Martinsburg, the marls are seen along Evans Run, also with solid blocks of the travertine. Its composition near where the run crosses the boundary line between the Standard and National tracts is given in No. 210.

Rockymarsh Run forms the boundary between Berkeley and Jefferson Counties at the north, and its banks are composed of marl which shows from south of the Martinsburg-Shepherdstown Pike and north. In the small run valley a half mile east of Greensburg are good deposits of marl, and its composition is shown by analysis No. 219.

Marl Analyses.

	No. 100.	No. 168.	No. 176.	"A".
Lime carbonate	88.18	91.53	94.70	92.26
Magnesium carbonate	0.93	1.44	1.06	1.54
Iron and alumina	0.59	0.82	0.72	2.46
Silica	4.76	3.55	1.72	1.80
Loss on ignition	5.15	2.49	1.70	.....

	No. 173	"B".	No. 210	No. 219
Lime carbonate	75.68	90.16	96.59	79.29
Magnesium carbonate	1.99	1.30	0.79	0.62
Iron and alumina	3.18	4.41	0.58	2.75
Silica	12.01	2.18	0.89	9.70
Loss on ignition	6.70	.....	1.33	7.61

Marls are used in Michigan in the manufacture of Portland Cement and would be valuable for this same purpose in this area. They also have an important value as land fertilizer either after burning into agricultural lime or when distributed over the land as natural marl. No use so far is made of these deposits in Berkeley or Jefferson Counties, but they form one of the valuable assets of the mineral wealth of the area.

DESCRIPTION OF QUARRIES AND PLANTS.

THE STANDARD LIME AND STONE COMPANY.

The largest operating limestone company in the eastern Panhandle area is the Standard Lime and Stone Company owned by Mr. Daniel Baker and other members of that family in Baltimore and Frederick, Maryland. This company was incorporated in 1888 with a capitalization of $100,000. The general offices are located at Baltimore and they operate quarries at Martinsburg, and in Jefferson County at Bakerton, Kearneysville, and Millville, also further west in the State at Keyser, Bowden, and quarries at Dickerson, Frederick, and Havre de Grace, Maryland, as well as near Strasburg, Virginia.

Mr. Daniel Baker was the pioneer in the limestone industry in this area, and his company at the present time ships the largest tonnage of any company in the field, practically all his product going to the Pittsburgh district. He controls over 1,000 acres of stone land in Berkeley County, and his plants at Martinsburg have a daily capacity of 3,500 tons.

Near Martinsburg this company operates a group of limestone quarries south of town which were opened about 21 years ago and consist of a series of pit openings with a length of nearly two miles. The belt of high-grade rock is 150 to 200 feet wide and it has been worked to a depth of 60 to 90 feet and a large quantity of stone has been removed. The quarries near town have been abandoned and the present work is in the holes furthest south and in a new quarry opened a few years ago to the west of the old quarry belt of stone. At the south end of the quarry development, the belt widens to about 500 feet and there is a large amount of high-grade rock yet available.

The Stones River Limestone which is the horizon worked is overlain by the cobbly Chambersburg higher silica and alumina stone which is removed by stripping along with the surface red clay. The contact between these two limestones is very sharp, the upper darker limestone being in strong contrast with the lower almost white rock. The limestone dips eastward at a high angle so that the surface Chambersburg rock rapidly increases in thickness as the quarry is worked eastward and in this direction profitable work soon ceases.

The Stones River Limestone in these quarries is similar to the other outcrops in the Martinsburg area. It is creamy-white to bluish-gray in color, very compact and brittle, and breaks with a shelly or conchoidal fracture, and is very low in silica and other impurities. The brittle character renders it easy to break in the quarry, a blow of the sledge shattering it into pieces. Fissures extend downward through the body of the limestone and are filled with red clay which must be removed in the quarry operation. These red clay filled fissures are not as numerous and large as in some of the other quarries where the high-grade limestone comes to the surface without the cover of high silica stone.

The south quarries of this company consist of nine openings which are 800 to 1400 feet long and 225 to about 400 feet wide, but the first five openings near town have been abandoned. The belt of these quarries is over 10,000 feet long with an average width of 250 feet, and they are reached by nearly 18,000 feet of standard gauge track and switches for the loading and transfer of cars to and from the Baltimore and Ohio Railroad.

The rock is blasted with dynamite and loaded by hand into two-yard quarry cars which are hauled by cable up inclines to the tipples or crusher. On account of the brittle character of the stone, it is shot light, with low-strength dynamite. A considerable portion of the stone is broken to one-man size and loaded from the tipples direct into railroad cars. For producing 8-inch stone and smaller sizes, the trucks of stone are hauled from the top of the inclines in the different quarries by small locomotives to the foot of the crusher incline and there raised by cable and dumped into the crusher. Air-drills are used in the quarries connected with a large type of compressor, and in this rock a driller can usually drill from 30 to 100 feet a day.

For many years a crusher in a large substantial building was operated near the edge of town, making necessary a very long haul from the quarries to the south. This wooden building was burned a few years ago, and a modern steel building erected further south and more central to the working quarries. This building is equipped with large Gates crusher, screens, elevators, and large storage bins, and is the main crushing plant.

At the south end of the quarry belt is a second crusher building equipped with Gates gyratory crushers Nos. 8 and 5, which is used to supply furnace stone and also stone for the adjoining fine-grinding works. All of the stone is screened through rotating cylindrical screens which are about four feet long and sixteen inches in diameter.

One of the important features of the equipment is the fine-grinding department which contains both Jeffrey and Williams pulverizers which crush the stone to a gravel. The ground material is dried in an Allis drier 40 feet long, and any finer grinding required is done in an Allis 22-foot tube mill to a flour. Storage is provided for 200 tons from the pulverizers and for 100 tons from the tube mill. In the sacking room the fine limestone flour is placed in bags, while the coarse-ground stone is loaded direct through chute into railroad box cars. The capacity of the plant is 200 tons daily and the product is shipped to the glass works, fertilizer works, etc. On account of the very pure limestone used, this material is in good demand, and more and more of it is finding a market as land fertilizer.

The Standard Lime and Stone Company also operates quarries at the west edge of town on a similar high-grade limestone. There are four quarry openings which average 400 by 300 feet each and are now worked to a depth of ten to thirty feet, and the property includes about 60 acres of stone land connected with the Baltimore and Ohio Railroad by a switch. There are four inclines and tipples and at these quarries the stone does not pass through a crusher but is broken in the quarry and loaded from the tipples into the railroad cars, with a daily capacity of 800 tons. The quarry is equipped with air-drills, compressor, hoist engines, and all necessary equipment.

Northwest of town on the railroad and near the switch to the western quarries, the company has ten stone-pot limekilns with daily capacity of 3,000 bushels of lime. There are three quarry holes here formerly used, but at present the stone is brought from other quarries. This lime made from the very pure limestone finds a good market for caustic lime in the leather and paper works. The stone from the adjoining quarries makes a good commercial building lime, but the company produces this grade of lime in late years at their large lime plant at Bakerton.

The Standard Lime and Stone Company with a far-sighted policy has bought various tracts of pure limestone through the county near railroad connections, which are held as a reserve supply for future demand. This reserve area probably totals near 1,000 acres.

Bakerton Quarries.—Engle Station is located 15 miles east of Martinsburg, in Jefferson County, on the main line of the Baltimore and Ohio Railroad. Bakerton is a small settlement located two miles to the northeast of Engle and connected at that place by a switch. At Bakerton are located the quarries and kilns of the Washington Building Lime Company owned by the Standard Lime and Stone Company. The plant was started in 1895 and is the largest center of lime-burning in the State, the lime from this stone being held in high favor in the eastern markets.

The quarry has been worked to a depth of 50 to 60 feet, the kilns being located at the level of the top of the quarry and close to it, and the rock is hauled up the incline tracks by cable and dumped into the kilns. The face of the quarry runs nearly north and south and the rock dips to the west. The cover of clay varies from 2 to 20 feet in thickness, being thickest nearest the ends of the quarry. The limestone is hard, compact, and somewhat crystalline. The lower 12 feet is marked by white calcite streaks. The next ledge of 12 to 15 feet above is blue in color and is used with the next upper 10 feet of light-colored stone. Under the red clay cover is a five-foot ledge of hard blue limestone not used for commercial lime. The limestone at this quarry was analyzed in the Survey laboratory with the following results:

	Per cent.
Lime carbonate	95.55
Magnesium carbonate	2.44
Silica	0.12
Iron and alumina	1.01
Sulphur	0.15
Phosphorus	0.02
	99.29

This limestone analysis was from the light-colored stratum and the lime is of very high-grade, not unlike the stone at Martinsburg in its chemical composition, but it seems to differ in its physical character as it burns into a more satisfactory commercial lime which is snow-white and strong. It is possible that the better results come from mixing the blue rock with the white.

There are 16 iron-clad draw kilns six feet in diameter and 20 feet high with a capacity of 250 bushels of lime each daily. There are three additional similar kilns located at Engle Station supplied with stone from the Bakerton quarries. There are also at Bakerton six stone-pot kilns for burning agricultural lime, each holding 300 bushels.

There is a Clyde system hydrator plant with a capacity of 12 to 15 tons daily of lime hydrate. This plant is also

PLATE XXVI.—Chimney Rock of Harpers Shale near Base of Blue Ridge, Opposite Harpers Ferry.

equipped with grinding machine for lime in the form of a Stedman cage disintegrator and a Jeffrey bag-packing machine, and a complete barrel plant with daily capacity of 1,000 barrels. The capacity of the Bakerton and Engle plants is about 35,000 bushels of lime a week.

This quarry and plant like all the other Standard Company plants is operated almost entirely by electric power with electric hoists, pumps, and air-compressor. This is one of the largest lime plants in the East.

Kearneysville Quarries.—Kearneysville is located in Jefferson County eight miles east of Martinsburg, on the main line of the Baltimore and Ohio Railroad. The Standard Lime and Stone Company opened quarries here in 1892, and for many years they furnished most of the B. & O. ballast from these quarries. The old quarry was 60 feet deep and worked nearly 500 feet square. A few years ago a new quarry was opened further up the ravine and is now about 40 feet deep at the lowest point. The rock is hauled in quarry cars up an incline to the crushers. The rock is of good hardness, and this is the largest ballast quarry on the railroad. It has a cover of red clay 3 to 20 feet thick. The lower solid rock of the quarry has the following composition as analyzed in the Survey laboratory:

	Per cent.
Lime carbonate	89.91
Magnesium carbonate	3.18
Silica	3.81
Iron and alumina	2.00

The stone is thus more impure than the flux rock at Martinsburg, but it is lower in these impurities than much of the limestone over the area and it was held in high favor for ballast, being harder than the pure limestone, with longer wear and less dust.

There are two crusher buildings equipped with five Gates crushers ranging in size from No. 7½ to 4, with screens, elevators, and storage bins, holding 25 cars of ballast. The quarry is equipped with hoist engines, air-compressor, air-drills, trucks, etc.

Millville Quarries.—Millville, in Jefferson County, is located on the Shenandoah Valley Division of the Baltimore and Ohio Railroad, four miles west of Harpers Ferry. The Standard Lime and Stone Company operates at this place large quarries in the dolomite or magnesian limestone which is shipped to Pittsburgh for basic steel manufacture. This locality is their main source of supply of this stone. They are without doubt the finest dolomites in the country, being nearly of theoretical composition.

The quarries were opened in 1901. The working quarry is one-half mile from the railroad track and is 50 to 60 feet deep. The rock near the center of the quarry has a bluish color becoming lighter near the ends of the opening and near the top. The rock is cut by numerous joint-planes. It is grayish-buff in color and quite compact. The cover is of red clay and varies in thickness from a few feet to 20. The composition of the dolomite is shown in the following Survey analyses:

	New Quarry.	Old Quarry.
Lime carbonate	54.72	55.00
Magnesium carbonate	43.18	45.00
Silica	0.05	0.40
Iron and alumina	0.89	0.41
Phosphorus	0.01	
Sulphur	none	
Alkalies	0.15	
	99.00	

The dolomite is almost of theoretical purity and the impurities are exceptionally low. It is thus a most remarkable deposit of this rock and its equal would be difficult to find in any other area. The company controls nearly 450 acres of this grade of stone.

The plant equipment includes a brick compressor house, crusher building with two Gates crushers, Nos. 6 and 5, with 16-foot revolving screen with perforations in the screen plates of 3, 2½, 1½, and ½ inches, large air-compressor, air-drills, hoist engines, etc., with electric power. There is a lime plant with two iron-clad 250-bushel kilns. The capacity of the quarry is about 1,200 tons daily. This magnesian limestone burns into a slow-setting lime which is regarded as equal to the famous Toledo district lime now shipped in such large quantity to the eastern markets in hydrate form.

BLUE RIDGE LIME AND STONE COMPANY.

Across the Shenandoah River from the Standard Lime and Stone Company quarries at Millville is the plant of the Blue Ridge Lime and Stone Company, formerly the Harpers Ferry Lime Company, owned by Pittsburgh parties, and opened in 1905. The rock was tested by them over an outcrop three-fourths mile long. Many years ago the Becker Brothers operated a lime-kiln at this place, and the present company has built three large Shoop lime-kilns of most modern construction with capacity of 350 bushels daily. They also installed two Champion jaw crushers for ballast and concrete stone. The disadvantage of the location is being across the river from the railroad so that the product was at first ferried across and later an aerial tram was built. If the river were bridged there would be a large production at this place, as the lime was sold in Washington and they were unable to supply the demand, the lime being held in high favor there by dealers and contractors. The plant has not been operated for some years, but was reopened in March, 1916.

The rocks in this area vary from high-grade limestone with 97 per cent. lime carbonate to pure dolomites. Magnesian and pure limes can be made and shipped east and west as well as south. The composition of the limestones at the quarries is shown in the following Survey analyses:

	Dolomite.		Limestone.
Lime carbonate	55.00	54.00	92.96
Magnesium carbonate	45.00	46.00	4.62
Silica	0.30	0.53	1.70
Iron and alumina	0.57	0.47	1.29

The dolomites are again seen to be very pure and the limestone should make a good high calcium lime, with opportunities to furnish dolomite rock and concrete stone. It is an operation so well equipped that it should be started up again and operated.

O. J. KELLER LIME COMPANY.

At Engle Station on the main line of the Baltimore and Ohio Railroad in addition to the Standard Company lime-kilns, there are located the quarries of the O. J. Keller Lime Company of Buckeystown, Maryland, which were opened in 1883. There are four patent draw kilns with a capacity of 300 bushels each daily, and five stone-pot kilns each with a capacity of 325 bushels a day. The patent kilns are of the Decker patent with three furnaces to the kiln and use coal. It requires about 7,000 pounds of coal to burn 325 bushels of lime in 24 hours. The kilns are drawn every two hours and the lime is packed in barrels holding two and a half to three bushels. The lower-grade rock was formerly burned in the stone kilns for agricultural lime and was darker in color due to the ash from the coal as the kiln was filled with alternate layers of coal and limestone.

The limestone at this quarry has a cover of red clay 6 to 15 feet in depth and the height of the present quarry-face is about 30 feet. The upper ten feet is more irregular than the lower and near the top is in rounded boulders, so that it was not used for the commercial lime. The lower 20 feet of blue limestone was used for the better grade of lime. The quarry has been worked back a distance of 1,500 feet from the railroad. This lime plant has not been in operation for the past few years. This quarry was leased in March, 1916, and plans made for reopening the plant.

The Keller Company opened in the fall of 1904 a new quarry three-fourths mile west of Engle Station, and operates under the name of the Potomac Limestone Company. This quarry is used mainly for ballast, though some of the purer rock is shipped for blast-furnace flux. The stone is crushed in two Gates crushers, Nos. 6 and 4, and in one Champion crusher. The daily capacity of these crushers is 400 cubic yards or about 700 tons.

The limestone at the Potomac quarry is worked in a 20- to 25-foot face and is blue in color. The cover of four to seven feet consists of buff shale, irregular limestone nodules, and clay. The limestone is broken by several belts of hard cream-white shales which are 20 to 60 feet wide and follow the trend of the limestone. The blue limestone between these belts is 20 to 30 feet wide. To the west of the first quarry these shale belts are smaller and even disappear. The bottom of the quarry is 75 feet above the railroad track so that a 100-foot face can be worked to the track level.

There are 180 acres in the tract and the cover is thin over most of it. Small belts of nearly white limestone are found near the east end of this quarry. The composition of the limestone is shown by the following Survey analyses:

	Blue.	White.
Lime carbonate	92.27	98.21
Magnesium carbonate	3.18	0.86
Silica	1.18	0.02
Iron and alumina	1.60	0.75
Sulphur	0.51	0.09
Phosphorus	0.08	0.007
	98.82	99.937

The analysis of the white limestone shows a very pure rock well adapted for high-grade flux stone. Only a limited amount was observed at this point, but this occurrence would suggest that more of the rock might be found by careful prospect work. The other or blue limestone has proved very satisfactory as ballast and is used by the railroad.

The belts of white shale or slate which are found in this quarry are not used, but they are of interest and have the appearance of a sericite mineral, and the plates are much crumpled. An analysis was made of this shale in the Survey laboratory, which shows it to be a magnesium aluminum silicate with the following composition:

	Per cent.
Silica	42.95
Alumina	9.13
Ferrous iron	1.00
Ferric iron	1.02
Magnesia oxide	12.15
Lime oxide	11.40
Sodium	0.39
Potassium	5 50
Water	2.02
Titanium	0.37
Phosphorus	0.77
Sulphur	none
Loss on ignition	13.15
	99.85

J. E. BAKER LIME COMPANY.

The limestone quarries near Bunker Hill, ten miles south of Martinsburg, were opened by Mr. Sam Cline about 1900, and lime was burned in two stone kilns with a daily capacity of nearly 1,000 bushels. About eight years later, the J. E. Baker Lime Company of York, Pennsylvania, purchased this tract of land and built a switch to the Cumberland Valley Railroad, and they have a capacity of 1,200 to 1,500 tons of fluxing stone daily. They also built a six-kiln lime plant which was destroyed by fire in 1914. The quarries are in the Stones River Limestone which outcrops at this place with a width of 250 to 300 feet and the quarries are now about fifty to sixty feet in depth. The stone is broken into blocks of one-man size and dumped over incline and tipples into the railroad cars. No crusher is used at this place, and the stone is mainly shipped to the Harrisburg furnaces. The silica averages under one per cent., and much of it under a half of one per cent., as shown by the following Survey analyses:

	1905.		1915.
Lime carbonate	97.17	97.05	98.20
Magnesium carbonate	1.26	2.63	1.29
Iron and alumina	0.46	0.47	0.19
Silica	0.60	0.59	0.29

BLAIR LIMESTONE COMPANY.

Three miles east of Martinsburg is the plant of the Blair Limestone Company owned by the Jones and Laughlin Steel Company of Pittsburgh. The company controls 550 acres of land on which are two belts of the low silica limestone. The property adjoins the main line of the Baltimore and Ohio Railroad. Flux stone is shipped to the Company's plants in the Pittsburgh district, and lime is also burned for use in their open-hearth furnaces.

They have 19 modern steel-clad kilns of Shoop pattern fired with coke. The kilns are eight feet in diameter and 40 feet high, with a daily capacity each of over 400 bushels. The company has recently completed a hydrating plant, using the Kritzer hydrator with six cylinders and Urschel-Bates automatic four-tube sacking machine. The machinery is housed in a steel building with steel storage building 40 by 200 feet, with a storage capacity of 3,000 tons of hydrate. There is a 2,500-ton steel storage tank for lime from the kilns, and the lime for the hydrator plant is taken by conveyor from this tank, while another conveyor can be used for loading the kiln lime from the tank into cars. A swing-hammer mill is installed for the manufacture of ground lime. The flux stone is crushed in a McLanahan single-roll crusher three feet long and eighteen inches in diameter which is fed through a 4- by 8-foot hopper, and has a daily capacity of 3,000 to 4,000 tons. This company also operates a dolomite lime quarry near Millville with five steel kilns.

The following analyses show the composition of the limestone at the Martinsburg plant:

Lime carbonate	97.54	98.30	98.98	98.42
Magnesium carbonate	1.50	1.21	0.43	0.57
Iron and alumina	0.72	0.46	0.88	0.27
Silica	0.72	0.40	0.58	0.74

The lime burned at this plant has the following composition:

Lime oxide	94.26	96.30
Insoluble	1.06	1.14

THE PITTSBURGH LIMESTONE COMPANY.

The Pittsburgh Limestone Company, a subsidiary of the Carnegie Steel Company, now controls a large acreage on the Potomac River north from Falling Waters and west of Williamsport, where there is a high cliff of the high-grade limestone. This place is about 14 miles north of Martinsburg and is reached by a branch from the Western Maryland Railroad from Charlton, Maryland. The limestone company has blasted away a large amount of stone for its tracks, and the quarry floor is laid with a branching system of quarry car tracks, and all was in readiness for sometime for the actual quarry work before the railroad was built. The shipment of stone and active work started in the fall of 1915. The stone dips gradually to the east and then to the west with a low syncline, so that the rock lies more nearly horizontal than in any of the other quarries in this area. The high vertical cliff affords a natural quarry-face to start on, and the stone is of very pure quality. The company plans eventually to operate this plant with an annual output of 1,000,000 tons.

SECURITY LIME AND CEMENT COMPANY.

Quarries have been worked for many years four miles north of Martinsburg near Berkeley Station on the Cumberland Valley Railroad. They were formerly operated under the name of the Bessemer Limestone Company, but changed in January, 1904, to the Martinsburg Limestone Company. They are now owned by the Security Lime and Cement Company of Hagerstown, Maryland. This company operates a Portland Cement plant at Security, near Hagerstown, and the lime and crushed-stone plant at Berkeley Station. The limestone is crushed for ballast, concrete stone, and for flux in a large size crusher in a modern crusher building equipped with screens, conveyors, elevators, and storage bins. The lime is burned in three large steel kilns fired with producer gas. Each kiln has a capacity in 24 hours of 1,400 bushels of lime. They find that the use of gas in burning gives a very uniform and even temperature. From the kilns the lime is carried by automatic conveyors to the crusher where it is reduced to the size of small pebbles, and it is then conveyed to a steel storage bin. Below this bin is the fine-crusher or granulator which reduces the lime to a flour and passes it by conveyor to a tightly closed bin. From this bin the lime flour passes to the rotary hydrator where it is hydrated with the proper amount of water and then stored in bins from which it is sacked by automatic machines. Hydrate lime, lump lime, and ground lime are sold.

NATIONAL LIMESTONE COMPANY.

One of the latest companies to enter the limestone quarry work in the Martinsburg district is the National Limestone Company with offices at Scranton, Pennsylvania. This company has the largest plant in the field and has expended in its operations probably over a half-million dollars. The plant is so different from any others in this section of the country that it will be described in some detail.

The quarries and plant are located two miles south of town and join the Standard Company property on the east. It owns over 1,000 acres of land at this place and has built two and a half miles of standard gauge railroad to connect with the Baltimore and Ohio Railroad. It has its own railroad equipment of standard gauge locomotives and quarry cars. The quarries were opened in July, 1910, and the plant was completed and at work December, 1911.

QUARRIES.—Two main belts of high-grade limestone come to the surface on the northern portion of the National tract, known as the East Fork and the West Fork belts, which unite at the north in a broad belt 1,000 feet wide, and nearly 450 feet north and south. The West Fork belt is about 3,500 feet long and the East Fork belt is nearly two miles in length on the property. These belts have been core drilled and show good stone to at least 140 feet down. Other belts of pure limestone are found to the west on the southern portion of the property. The present quarry openings are on the East Fork belt near its northern end.

The quarry excavation and loading has been by steam-shovels and two were used, one 110-ton and one 60-ton. The stone was loaded in 15-ton standard gauge steel cars which were automatically dumped at plant. The first quarry was opened as a long open cut northward with the trend of the ledges, and then the side walls were turned over into the cut by heavy blasts. This cut is now about 1,400 feet long and 100 to 140 feet wide, with a height of face of 65 feet. Throughout this extent of face, analyses show an average silica contect of under three-fourths of one per cent.

The drilling in this quarry is by two Clipper gasoline engine well drills which drill a five-inch hole at the rate of 40 to 45 feet daily. Very few quarries in this section use this form of drilling which represents a marked saving in cost of throwing down stone. With the well drill, a row of holes is drilled back from the face of the quarry and about 20 feet apart and to a depth a few feet below the floor of the quarry. In the bottom of the hole 75 to 125 pounds of dynamite are exploded to form a cavity, a method known as springing the hole to form a space for the charge of dynamite. This space is usually filled with about 40 per cent. dynamite and a lower strength used above, filling the lower third or in some cases the lower half of the hole and then loose clay is tamped in. Seven to ten or more holes are shot in one blast. The heavy charge in the bottom blows that portion of the ledge outward and the upper portion falls in. Blasts at this quarry have been made with from one to three tons of dynamite.

The second quarry was opened to the south of the first as a hand operation with inclines and hoists, but later was converted into a steam-shovel quarry. This quarry is worked with a very long north-and-south face and narrow width, and water is more troublesome than in the much deeper number one, but is kept down by a large electrical pump.

A third quarry was opened just ahead of number one, as a hand operation but the large amount of red clay in its surface ledges caused its abandonment. Red clay fissures extend in all these three quarries to the bottom and widen out here and there making much trouble in their removal. In fact the loading by steam-shovel has not been entirely successful on account of the quantity of this clay, and most of the high-grade stone is now being quarried by hand methods as in the other quarries.

This high-grade stone being very subject to solution is bound to have solution fissures and along joint-planes will have deposits of this surface clay. The shovel does not sort the stone and clay so that it will not be a success in such limestone highly tilted as here except in most favorable weather. In dry weather this clay crumbles like sand and then will be separated on the screens and make little or no trouble in the stone. In wet weather and especially in winter, the clay is sticky and forms large resistant balls that will not break up and can not even be broken by the pick. Such balls will pass over the screens and go in with the stone for shipment thus injuring the product. Where it can be used, the steam-shovel is the most economical method of quarrying stone. The blocks can be loaded in larger size which means lower blasting cost, and less laborers are required and higher capacity a day is produced. On test runs in good weather the limestone has been quarried, crushed, and loaded on railroad cars at this plant by use of shovel without being touched by hand from quarry-face to car and at a cost as low as 17 to 20 cents a ton on a day's run, while the cost by ordinary methods will average close to 35 cents per ton under most economical working. While experts differ on this subject, it seems to be well proved that the shovel can not be depended upon in this high-grade stone in the Martinsburg district month in and out in the variable weather conditions. They should be held in reserve and used when weather is favorable to increase the tonnage at such times. Inclines are also in use to insure a steady output for the regular market.

On the ballast and lime-burning stone which is harder and more resistant to solution, the clay seams will probably practically disappear at depths of 15 to 20 feet and the shovels could there be used at a profit. On the National tract as on the other limestone company tracts in this area there is a far larger tonnage of the so-called low-grade stone which could be worked for these other purposes and plants should be equipped to enter the different stone markets and use all their stone resources. This is not usually true, as they depend on one kind of stone at a given place probably on the theory that the two kinds of stone can not be worked together without some accidental mixture thus spoiling the pure flux stone. In the large Ohio quarries, the work is carried on both lines of low and high silica stone and without any trouble. Some of those quarries run by day on flux stone and at night on ballast. This insures a varied market so that when business is dull on one line they can crowd the other. In this section the flux stone is also crushed for ballast and seems to find a good market. In reality it makes a very poor ballast being readily crushed on the road-bed and proves quite dusty, further it is too valuable to be used for this common purpose and should be reserved for the steel trade and for caustic lime. Adjoining the high-grade stone is nearly always a hard bluish-black to black limestone or dark-gray, hard, compact, resistant limestone of the Beekmantown Formation that is an ideal ballast rock. If the railroads would begin using this rock they would soon not even consider the white brittle rock. Yet at the present time there is not a company in this section quarrying this grade of rock of which there is such a large quantity.

The National Company has opened a quarry in the broad area at the north where the East and West Fork belts seem to come together. This is a very favorable location for large quarries and it is worked by hand, loaded into quarry cars and hauled by small engines some distance to a small gyratory crusher and there reduced to proper size and loaded direct into railroad cars. This quarry is about 25 feet deep and so far there is no water in it and no pumping required. The stone is of the same high-grade as in the other openings. The main belts of pure limestone on this property average 250 feet in width and there is a very large tonnage available. The stone from the quarries is crushed in the small crusher at the fourth quarry, and in the others is loaded direct on cars as one-man stone or hauled to the plant and there crushed.

The National plant is a modern steel and concrete building equipped with the latest and most efficient, large-capacity and labor-saving machinery. It is so different in its operation from the other plants that it merits a detailed description. The building is fire-proof and covers a floor space 50 by 220 feet and is 60 to 110 feet high.

The low building at the right has two floors. On the upper floor is the hopper of the crusher and the railroad tracks; on the lower are the crusher and motors, with a pit below, 36 feet in depth, containing the lower discharge hopper, tracks of the skip hoist, and smaller motors. The tower building, seven stories in height (110 feet), contains the screens and storage hopper and bin. At the top of the building the skip cars on the hoist discharge their loads of crushed stone over the screens into the storage bins. A third building not yet erected will contain the fine-grinding machinery and sorting screens for by-product manufacture.

The central feature of the whole operation of this plant is the great crusher, the invention of Thomas A. Edison, and installed by the Edison Crushing Roll Company. This crusher consists essentially of two rolls seven feet long and six feet in diameter, on which are bolted heavy iron plates containing numerous projections or knobs. These knobs are of the same size and shape about two inches high, except on one roll, the slugger, which has two rows of slugger plates on diametrically opposite sides of the roll, on which the knobs are of little greater height and steeper face.

Each roll complete with plates weighs 45 tons, and they are set parallel and revolved in opposite directions by separate 200-horse-power motors at a velocity of 175 revolutions per minute. The knobs, and especially the slugger knobs, thus strike the rock like a multitude of sledge hammers, shattering rather than grinding the stone, with a low percentage of fines or screenings. Large blocks of 8 to 10 tons weight are thus broken in a few seconds of time. The rolls are readily adjusted in distance apart, and may be set to crush to eight inches, or to blocks several feet in diameter.

The upper hopper of the crusher will admit blocks 7 to 10 feet in size. A block of 20 tons weight was crushed in this plant, consuming 25 seconds of time. This would be at the rate of 3,000 tons per hour. The theoretical capacity computed from the size of the rolls and revolutions per minute is about 55,000 tons a day. The working capacity of the rolls depends on the capacity of the elevators for removing the crushed stone from the crusher, which at the National plant is 1,000 tons an hour, or 10,000 tons a day.

The advantages of the Edison roll crusher are, low blasting cost at quarry as larger blocks can be used, low percentage of screenings due to the sledge-like action of the rolls, low labor cost as 10 to 12 men represent the total force required to operate the entire plant, car loading and switching.

In nearly all crushed-stone plants the rock is transferred from the crusher to the top of the elevated screens by bucket with three switchboards with automatic magnet controls.

When the quarry cars come to the plant, the car is stopped at the side of the hopper and the hoist cable attached to the side of the skip on the quarry truck, which is raised and tipped into the hopper by an electric automatic hoist operated by a 50-horse-power motor. After unloading, a reversal of the machine drops the skip back into place on the car truck. A 15-ton load of stone is dumped and the skip set back in place ready for another car to dump in one minute.

CHAMBERSBURG LIMESTONE.

Above the Stones River Formation is the Black Rivèr or Chambersburg Limestone with a thickness of 200 to about 600 feet, which shows a tendency on weathered outcrop to form a cobbly surface due to weathering along cross joints filled with clayey material. The basal layers are very shaly in many exposures and they disintegrate under the weather, while the upper ledges are more massive and would form a good quarry rock. This limestone forms narrow outcrops along those of the Stones River in typical exposures separating that formation from the shales.

It is used in a few places in small openings to supply stone for public roads. One quarry was opened some years ago at the side of the Cumberland Valley Railroad one-half mile northeast of Falling Waters and used for ballast during the construction of this railroad. It here is a dark-gray limestone, quite hard, and breaks with a slightly shelly or conchoidal fracture. It contains stringers of calcite, also rhombic crystals of this mineral along the joint-planes. The ledges are solid so that large blocks could be quarried. The stone on analysis (No. 1) runs a little over 4 per cent. silica. This limestone outcrop is surrounded by shales, being a small anticline projecting above the surrounding shales. It extends north to the Williamsport Pike and south to Bedington with a length of five miles. It could be opened at a number of different places on this outcrop, but at this quarry the stone is well opened

PLATE XXVII.—Quarry in Upper Stones River Limestone at Security Lime and Cement Company, Four Miles North of Martinsburg.

with a face exposed of 12 to 15 feet, and it should be a valuable location for an operating quarry to supply stone for the county roads.

A small road quarry was opened in this same limestone on another outcrop one-half mile northwest of the Falling Waters Schoolhouse, or about a mile distant from the last-named quarry. The rock on analysis shows a very similar composition (No. 8), but runs somewhat higher in magnesia. This limestone dips 20 degrees southeast and is black or dark-blue in color, very hard with slightly shelly fracture. The opening is small, but the run forms waterfalls over a number of ledges of this stone, and a good road material quarry could be opened here.

The Chambersburg Limestone along the belt where the first sample was taken was again sampled on the south bank of the Potomac one mile to the south where it presents a similar appearance to the number 8 outcrop, being a hard, slaty black limestone, but it weathers to a light-gray color and breaks along smooth surfaces. In chemical composition (No. 40) it is quite similar to that at the quarry on the same belt above Falling Waters at the railroad.

The three analyses show a close agreement in chemical composition in locations more or less distant from each other. There is a large quantity of this Chambersburg Limestone over the area and to the eye the limestones in the different outcrops appear to be quite constant in their character.

	No. 1.	No. 8.	No. 40.
Silica	4.20	4.04	3.87
Lime carbonate	91.71	90.61	92.63
Magnesium carbonate	2.54	4.08	2.41
Iron and alumina	1.85	1.59	0.62
	100.30	100.32	99.53

BEEKMANTOWN LIMESTONE.

A narrow belt of Beekmantown Limestone is faulted against the Martinsburg Shales at the foot of North Mountain to the south of Hedgesville. A sample of this belt was taken on the Dry Run grade road just west of the lane to the south, (No. 49).

A broader belt extends from the Potomac west from Falling Waters, southwest to Martinsburg across the county. Another broad belt extends from the river in the northeastern corner of the county southwest by Kearneysville, Summit Point, to the Virginia Line. No large quarries are opened in the two western belts, but numerous roadside quarries have been opened to supply road material. In the eastern belt there are large quarries for ballast at Kearneysville, which are described in a previous section of this Chapter.

At a number of places, especially in the eastern Beekmantown area, strata of fairly high-grade limestone outcrop. While they are not as low in silica as the Upper Stones River Limestones, yet they represent very pure limestone. They are of doubtful value for open-hearth steel flux, but are valuable in a number of other ways. These higher-grade Beekmantown Limestones are described in the next Chapter. The dolomites of this formation are discussed under that heading in a preceding section of the present Chapter.

Over much of the outcrop, the Beekmantown Limestone is a solid-bedded rock of compact texture, available for roads, ballast, or lime. It often has a bluish-gray to blue color, and is seamed by calcite. It is a durable rock on exposure and large quarries could be opened at many places near the railroads, as at Martinsburg, Van Clevesville, to Kearneysville, and south near Summit Point, and west of Charlestown, also at various points southwest of Martinsburg on the Cumberland Valley Railroad.

The Potomac River is bordered by cliffs of Beekmantown from the new railroad grade west toward dam No. 5. Most of the ledges are rather high in silica and magnesia, but there are also ledges of fairly low silica stone. Samples were taken at a number of places along these cliffs. No. 11 is the limestone from the small quarry west of the Pittsburgh Limestone Company's quarries. No. 12 was 700 feet east of the new railroad. No. 13 is from a small quarry opened just west of the railroad grade to furnish stone for the concrete piers of the river bridge. No. 14 is from a series of ledges with width of 75 to 100 feet and located 50 feet west of the railroad grade quarry. No. 15 was taken about a mile west of the grade.

Further south and about one-eighth mile west of Hainesville toward Nipetown, sample No. 47 was taken, while No. 48 is of exceptional low silica rock for this formation and suggests Stones River. This sample was taken on curve of road just east of Nipetown. On this belt just west of the Cumberland Valley Railroad at Darkesville, No. 188 was taken. On the belt east of Opequon, sample No. 29 is from the county road just south of the bridge over the creek near its mouth.

	No. 49	No. 11	No. 12	No. 13	No. 14
Lime carbonate.......	53.96	89.64	91.66	87.00	89.20
Magnesium carbonate.	32.50	7.26	6.16	7.32	2.61
Iron and alumina.....	3.82	0.85	0.71	0.80	1.24
Silica	9.43	2.49	1.37	4.66	6.10
	99.71	100.24	99.90	99.78	99.15

	No. 15	No. 47	No. 48	No. 188	No. 29
Lime carbonate.......	94.20	98.59	98.47	93.79	89.61
Magnesium carbonate.	3.09	0.88	0.77	3.12	6.34
Iron and alumina.....	0.26	0.39	0.25	0.41	0.45
Silica	2.64	0.42	0.80	2.69	3.97
	100.19	100.28	100.29	100.01	100.37

No. 49 from the narrow belt near the mountain is seen to be a dolomite, high in silica. It has a light-gray color and weathers almost white. It shows numerous streaks and spots of calcite. No. 11 is under the dolomite (No. 10, page 386) and is dark-gray, compact in some ledges, and granular in others. It breaks with shelly fracture and so resembles the high-grade limestone but the silica is high for the pure limestone. No. 12 is lower in silica than the last and varies in color from light- to dark-gray. It shows some bird's-eye calcite and breaks with smooth surfaces and resembles in outcrop the Upper Stones River. A few ledges are coarsely granular composed of a mass of calcite rhombs in a less granular matrix.

No. 13 from the railroad small quarry is higher in silica than the others further east. This limestone shows small Gasteropod shells and some oolite. It is dark-gray in color, and "edgewise beds" are found in the limestone on the railroad grade, above this rock. It dips east 65 degrees, and is a very hard, mostly compact limestone. No. 14 is a dark-gray limestone and mostly compact with a few granular lighter-gray ledges. No. 15, nearly a mile west of No. 14, is a light-gray limestone breaking with smooth surfaces and looks on outcrop like a fairly high-grade limestone. It is high in carbonate of lime and contains calcite. This outcrop is 150 feet wide and dips 80° east. Nos. 47 and 48 are very unusual types for Beekmantown and would be classed by appearance and composition with Upper Stones River, but stratigraphically they are in the Beekmantown. No. 188 is a very dark limestone, almost black, and represents a large surface area in this locality of Darkesville. No. 29 is a very dark, almost black, rock with stringers and nodules of calcite. It weathers to a gray surface, and some of the ledges are bluish-gray color and somewhat granular.

THE CONOCOCHEAGUE LIMESTONE.

Extending from the Potomac River to the east and west of Little Georgetown and thence southwest is a broad belt of the Conococheague Limestone which is opened at some places for small road material quarries, but no regular work is carried on in them, and they are merely small holes, scarcely deserving the name of quarries. This limestone is found in many places over the area in solid ledges which are very hard and apparently durable under the action of the weather. Some of this stone has a bluish-gray color, that if durable should make a beautiful trimming stone for buildings. This stone is seen in foundations and in stone houses over the belt, some of which date back over a hundred years, yet the stone is solid and firm and of good color, and the houses look as if they might have been built in recent years. Ornamental effects could be obtained by the use of the oolitic ledges or the banded stone which when polished would have an agate-like appearance.

Some of the ledges on analysis show a remarkably pure rock, high in lime carbonate and comparatively low in silica, but the average outcrops show a higher percentage of silica and the formation is often described as a siliceous limestone which is not strictly correct. The silica is not high enough to form a siliceous rock. Pink marble is described in the formation in Pennsylvania, and in this area some of the ledges show a pink cast. The outcrop of the formation along the railroad cuts shows massive ledges from which blocks of large size could be obtained, and would give encouragement to good stone in quarries at shallow depths.

Another broad belt of this limestone outcrops in Jefferson County from the Potomac River north of Shepherdstown at Terrapin Neck southwest across the county. In this belt the stone is quarried on a small scale here and there for road material, but like the Berkeley County belt no great use is made of this limestone and no large quarries have ever been opened.

This stone should be valuable in its higher-grade strata for lime. Many ledges would make a durable and pleasing building stone. On account of its hardness it would make a very durable ballast for railroads. It is a good road material, and greater use along this line should be encouraged for the benefit of the roads, especially in Berkeley County. It is much more valuable for roads and ballast than the Stones River low silica limestone which is too brittle for No. 1 ballast.

The siliceous banded limestone of this formation would run high in silica, and much of the limestone is very siliceous. Ledges of fairly pure limestone occur in which the silica is not very great in amount. One outcrop was sampled near Spring Mills (No. 43), and another of the limestone one and a half miles north of Duffields in a roadside quarry on the Shepherdstown road just north of fork east to Uvilla (163). Sample "A" is this limestone at Shepherdstown, "B" is just west of the town, while "C" is the siliceous banded rock east of town not far from cement quarries.

	No. 43	No. 163	"A"	"B"	"C"
Lime carbonate.......	93.72	71.09	83.61	80.69	48.47
Magnesium carbonate.	1.92	13.94	6.19	7.48	28.95
Iron and alumina.....	1.12	3.69	2.40	3.90	8.33
Silica	3.13	10.65	6.24	5.21	13.18
	99.89	99.37	98.44	97.28	98.93

ELBROOK LIMESTONE.

Below the Conococheague Limestone is the Elbrook Formation composed in large part of flaggy or shaly buff limestones which weather to shales or thin flaggy plates. In the formation are flaggy and solid ledges which have the proper composition for the manufacture of natural hydraulic cement. This cement limestone outcrops in the high bluffs along the Potomac east of Shepherdstown and was there made into cement for many years. This industry and the limestones of the river cliffs are more fully described in Chapter XVI of this Report.

In these cement limestone cliffs, the limestone is high in magnesium so that they are dolomitic limestones and some of the ledges are high in silica and break with a sandy surface. These are illustrated by the following analyses made in 1905 for Volume III (p. 512) of the Survey Reports. No. 51 was used at the mill but burned to a clinker which had to be ground. Nos. 106 and 112 were regarded as especially adapted to the cement manufacture. No. 108 is a blue rather hard limestone of higher degree of purity, but it was not adapted to the cement manufacture, while No. 114, a rather thin ledge only a few feet thick, is of exceptional purity for this formation and it is an unusual type in the Elbrook:

	No. 51	No. 106	No. 112	No. 108	No. 114
Lime carbonate.......	43.67	47.42	68.79	90.18	94.82
Magnesium carbonate.	21.99	29.78	17.04	3.27	4.45
Alumina	11.55	5.68	2.72	0.91	0.08
Iron	3.29	2.06	1.63	1.03	0.82
Silica	16.73	13.44	10.32	4.84	0.70

Near the middle of the Elbrook Formation are solid ledges of dolomitic limestone, often banded and resembling the Conococheague. These are exposed in the railroad cuts west of Cumbo, along the Baltimore and Ohio Railroad east of Duffields, east of Charlestown, and Rippon, and a number of other places. The hard dark-blue Elbrook Limestone was sampled at Charlestown below the red clay at the Valley Brick Company pits, No. 178, which shows a limestone rather low in silica, but magnesian:

	No. 178
Lime carbonate	86.29
Magnesium carbonate	11.17
Iron and alumina	0.52
Silica	1.73

A large portion of the Elbrook Limestone outcrop is a shaly limestone grading into shales. A sample of the Elbrook Shale was taken on the county road about a half mile south of Reedson (172). The analysis shows it to be very low in lime, but fairly high in magnesia and potassium. It is a magnesium aluminum silicate shale:

	No. 172
Silica	56.11
Alumina	15.75
Iron oxide	6.81
Lime oxide	1.04
Magnesium oxide	8.19
Potassium oxide	4.19
Sodium oxide	1.58
Water	0.57
Loss on ignition	5.52
	99.76

WAYNESBORO LIMESTONE.

A small outcrop of the Waynesboro Formation is found along the foot of North Mountain south from Hedgesville, but the large outcrop is in the eastern part of Jefferson County. It is composed of shales, sandstones, and limestones. It is quarried on a large scale at Engle, and Bakerton, two miles north of Engle Station; also in numerous small roadside quarries. It is burned into lime at both of these towns, and also crushed for ballast at Engle. These quarries have been described in a preceding section of this Chapter. The limestone is low in silica with fairly high percentage of lime carbonate as shown by the analyses given under description of these quarries.

In the formation are white and bluish-white marbles, finely granular and glistening, which have never been worked except for road material. There also occur very hard, deep-blue limestones, and siliceous blue limestones. Associated with the marble are sericitic limy shales. The limestones are burned at various places in field kilns for agricultural lime, especially in the Moler Crossroads section of northeastern Jefferson County.

A number of analyses were made of the limestones from these small quarries. No. 151 is from a roadside quarry in the deep-blue, hard limestone, three-fourths mile northeast of Reedson. No. 179 is the white marble higher in the Waynesboro and from near Flowing Springs north of Charlestown. No. 158 is from a field quarry for lime located three-fourths mile northeast of Moler Crossroads in the northeastern part of Jefferson County. It is a white marble, compact, and associated with the sericitic shales. A half mile further northeast in the bed of the run is an outcrop of gray dolomite, No. 159. Further down this run is an old quarry and abandoned lime-kiln. The limestone is dark-blue, No. 160. About 100 feet from the Potomac River on this run are heavy ledges of dark-blue, very hard limestone, with sandy weathered surfaces, No. 161.

	No. 151	No. 179	No. 158	No. 159	No. 160	No. 161
Lime carbonate......	92.23	93.82	91.59	46.44	97.36	66.18
Magnesium carbonate	4.95	3.15	5.31	33.80	1.85	21.77
Iron and alumina....	0.51	0.37	0.35	5.05	0.22	0.99
Silica	1.62	2.30	2.52	12.90	0.34	11.41
Potassium oxide.....	1.19	.....	.....	1.66	.....	.....
Sodium oxide........	0.36	.....	.....	0.33	.....	.....
	100.86	99.64	99.77	100.18	99.77	100.35

The Waynesboro Limestone was sampled on the east-and-west lane a mile south of the Potomac and a mile and a half north of Moler Crossroads, No. 162, which is a white marble. A mile and a half east of Engle, in the blue hard limestone outcrop, are ledges of granular, crystalline dolomites, gray in color, No. 192. No. 171 is a grayish-white siliceous limestone or shale on the road just south of the Engle quarry. No. 174 is a similar rock but harder and more compact with some sericitic surfaces and located just south of railroad track on county road a mile west of Halltown. The white marbles were sampled near Kabletown. No. 167 is just west of the Kabletown Pike on the road that leads northwest to Charlestown about a mile and a half north of Kabletown. No. 169 is from roadside quarry on Bullskin Run, just west of Kabletown.

	No. 162	No. 192	No. 171	No. 174	No. 167	No. 169
Lime carbonate......	94.90	47.21	28.05	38.08	70.80	95.03
Magnesium carbonate	2.50	34.33	17.01	33.29	24.68	3.30
Iron and alumina....	0.23	1.68	21.46	4.03	0.82	0.49
Silica	2.60	15.90	29.61	22.26	3.45	1.27
Potassium and sodium oxides	.....	0.36	4.39	2.21	.....	.....
	100.23	100.56	100.58	99.87	99.75	100.09

The peculiar smooth sericitic shales with soapy feel and cream to greenish-gray color associated with the white marbles of the Waynesboro are very common. They form broad belts in the Potomac Limestone Company quarry at Engle. No. 152 sample was taken three-fourths mile northeast of Reedson and about 500 feet east of the blue limestone sample No 151. It is over the white marble. No. 221 is the sericitic shale with the limestone near Dupuy Mill, about two miles west of Harpers Ferry. "A" is from the Engle quarry from sample taken in 1905:

	No. 152	No. 221	"A"
Silica	24.49	22.73	42.95
Alumina	12.77	0.90	9.13
Iron oxide............................	3.57	1.31	2.02
Lime oxide............................	21.08	24.59	11.40
Magnesium oxide.......................	7.33	15.25	12.15
Potassium oxide.......................	1.96	1.82	5.50
Sodium oxide..........................	0.68	0.69	'0.39
Loss on ignition......................	3.72	32.29	15.17

TOMSTOWN LIMESTONE.

The Tomstown Limestones below the Waynesboro are only found in this area in two outcrops in the eastern part of Jefferson County. In the northern outcrop east of Bakerton, dolomites and a blue siliceous limestone are associated with the iron ore deposits. No. 155 is a bluish, hard, slightly granular dolomite below the red clay and ore deposit. No. 153 is further west on the county road and is not associated with the ore but looks like the same limestone. No. 200 is a light-blue limestone, very hard and in almost horizontal ledges formerly quarried for road material. Under lens it is very granular in texture. This outcrop is south of the ore mines in a field near the road, and differs from the ore dolomite in color, texture, and inclination of the beds. No. 156 is a brown, irregular limestone, full of dolomite crystals in stringers and cavities and closely associated with the iron ore, and contains 7.6 per cent. iron oxide.

The only large quarry in this outcrop is at the north end on the river bank where the Knott quarry was opened many years ago and stone shipped by the canal to Washington, where it was burned into lime. This quarry has been abandoned for several years, but the Standard Lime and Stone Company opened a quarry south of the Knott to furnish limestone to its Bakerton kilns. The two quarries are now practically connected.

The limestone worked at this Standard quarry is a dark-blue, seamed by calcite, and somewhat granular texture. It gives a fetid odor when struck with hammer. The west wall of the quarry is a white marble which was sampled, No. 157:

	No. 155	No. 153	No. 200	No. 156	No. 157
Lime carbonate	52.62	54.75	52.35	85.47	98.65
Magnesium carbonate	42.96	43.68	41.86	1.23	0.95
Iron oxide } Alumina oxide }	0.59	0.57	0.64	7.60	0.26
				0.58	
Silica	2.44	0.95	3.68	4.29	0.47
Potassium and sodium oxides	0.58	0.58	.....	0.91	.....
Loss on ignition	.....	.....	1.29	......	......
	99.19	100.53	99.82	100.08	100.33

The Millville dolomite outcrop east of this town and north to the river was regarded as Tomstown but apparently is in the Waynesboro. These rocks are described in a preceding section of this Chapter under the head of dolomites.

OTHER LIMESTONES OF THE AREA.

BOSSARDVILLE LIMESTONE.

The Bossardville Limestone of I. C. White or Tonoloway of the U. S. Geological Survey, outcrops on both sides of Ferrel and Wilson Ridges in Back Creek Valley of Berkeley County; and in Morgan County along the west side of Warm Spring Ridge, and on the east side of Tonoloway Ridge. Its characteristic feature is a distinct light- and dark-banding, giving an agate-like effect, the so-called "ribbon limestone" of the Pennsylvania Survey. This structure is well shown on the edges of the blocks, and resembles foliation planes, but the rock does not break along them. The limestone is usually bluish-gray to dark-gray in color, breaking in slabs or somewhat angular blocks.

This limestone is quarried in roadside cuts for road material and was formerly used north of Jones Spring in Back Creek Valley for lime. It is used for lime at a small one-kiln plant on the west slope of Warm Spring Ridge about three miles southwest from Berkeley Springs. The rock runs rather high in silica for a good lime and its use has been abandoned at the Jones Spring locality where the Helderberg Limestone is now used. The plant on Warm Spring Ridge only runs intermittently as a local demand arises. Some of the ledges weather quite shaly and are not then suitable for road work, while other ledges are solid but not very thick, and are suitable for roads.

At the lime-kiln southwest of Berkeley Springs, the limestone is slaty, black-colored, breaking in platy blocks with somewhat wavy surfaces, and is hard and compact (No. 72). On the east slope of Tonoloway Ridge, the limestone is a bluish-gray, not very dark, and again slate-colored, and weathers to a grayish-buff. It is close-grained and breaks in platy blocks with quite smooth surfaces (No. 86), and is a dolomite high in silica. There is a long outcrop of this limestone in the railroad cut one mile west of Hancock Station and near the mouth of Grasshopper Run, where it forms a high cliff of slaty gray limestone almost black in color and breaks in tabular blocks (No. 77).

This limestone near the top of Ferrel Ridge on the west slope and to the west of Butts Store varies from light- to dark-gray color and has a sandy appearance and is high in silica. It is compact and breaks in the smooth blocks which show the striated edges, some of the folia being quite wavy (No. 51):

	No. 72	No. 86	No. 77	No. 51
Silica	6.23	16.63	6.94	13.69
Lime carbonate	85.54	44.59	79.24	76.02
Magnesium carbonate	3.98	30.49	10.76	5.10
Iron and alumina	2.79	5.28	2.65	4.41
Loss on ignition	1.12	3.69	0.04	.....
	99.66	100.68	99.63	99.22

RONDOUT WATERLIME OR WILLS CREEK FORMATION.

Below the Bossardville Limestone at the localities given above for its outcrops is the Wills Creek Formation of the U. S. G. Survey or the Rondout Waterlime of the New York Series, consisting of limy shales and shaly limestones which near Cumberland, Maryland, and in New York State were burned into a natural cement or waterlime.

The natural cement industry is of very little importance at the present time as compared with that of Portland cement, or as compared with its history twenty years ago. It is very doubtful if any capital could be obtained to start a natural cement plant on the best grade of materials in the country in the most favorable locations. In this area such plants are out of the question, so the value of this formation on this line is nothing.

In many of the outcrops this formation would furnish the basis for natural cement, and such cement was made on the east slope of Tonoloway Ridge when the Chesapeake and Ohio Canal was building. In other outcrops the percentage of alumina would be too low for this use. As a road material it is not as valuable as the other limestones found near it. The shaly character results in rapid disintegration, and it is not much of an improvement over shales.

An analysis was made in the Survey laboratory of a sample taken on the county road about three-fourths mile west of Tomahawk, which shows the high content of silica and the low percentage of lime carbonate. It is in reality a shaly limestone over most of the outcrop:

	Per cent.
Silica	25.90
Lime carbonate	61.47
Magnesium carbonate	3.33
Iron and alumina	7.72
	98.42

HELDERBERG LIMESTONE.

Above the Bossardville Limestone is the Helderberg which outcrops along the east side of Tonoloway Ridge and the upper west slope of Warm Spring Ridge. It is also seen west of Cherry Run Station and on Ferrel Ridge. It is a granular limestone, bluish-gray to deep-bluish almost black color, glistening with calcite plates and usually full of fossils. Some of the ledges are compact and slaty in texture, and near Tomahawk certain ledges are high in silica. These limestones are quarried and crushed at a small plant on the west slope of Warm Spring Ridge near Berkeley Springs, and are burned for lime at the Wheeler kilns north of Jones Spring in Berkeley County. They make a good quality of lime which appears to be in good demand among the farmers of the Back Creek Valley. They are also burned for lime west of Ridge Store, fourteen miles south of Berkeley Springs.

The number of good outcrops and the favorable locations relative to economy of working and to the farms over various parts of the counties of Morgan and Berkeley, should lead to a greater development of these limestones. They are also most excellent road materials and a number of small openings have been made for this purpose. The Helderberg Limestones carry several flint strata and this hard flint has also been used on the roads, making a very durable bed.

There are a number of places along the Warm Spring Ridge that this stone could be opened to advantage and a large tonnage obtained. The outcrop is rather narrow but it extends nearly the length of the ridge. A sample was taken of the ledge at the crushing plant near Berkeley Springs (No. 74). The stone is here obtained from a pit quarry elevated and carried down the slope by overhead cable to the crushing plant. The stone is a dark-blue in color, quite hard and makes a very good road material. It is now obtained from an open quarry near level of top of incline to the plant. The county has not taken advantage of this stone as much as it should, and the roads in this section should be covered with limestone which would be cheaper in the long run than the shales so extensively used at present. This belt outcrops in the Baltimore and Ohio Railroad cut one-half mile west of Hancock Station, where it is a slaty gray, hard limestone, breaking irregularly and quite compact (No. 79). A little further east in this same cut, the ledges are coarsely granular and quite brittle with light-pearl-gray color (No. 78).

The anticlinal small outcrop of Helderberg Limestone three-fourths mile west of Cherry Run Station in the railroad cut and south to the county road shows a dark-gray granular rock with crystal lime plates and full of fossils and carries a considerable percentage of silica. Some of the ledges are very siliceous. An analysis of the better limestone was made in the Survey laboratory (No. 64).

The outcrops along Ferrel Ridge in the Back Creek Valley are of good width and extent for lime and road material quarries and should attract more attention, as the district is a considerable distance from railroads with freight charges on the lime and long wagon hauls.

At only one place is any great use made of this limestone in this section and that is at the lime-kilns one mile north of Jones Spring. Here **Mr. J. H. Wheeler** has two small plants. At the lower plant is one iron-clad lime-kiln with daily capacity of 170 bushels of lime, and it is located 90 feet below the quarry with gravity haul to the plant. The quarry has 6 to 8 feet of cover, then one foot of hard blue limestone not used, and below this a 6-foot bouldery ledge of good stone with 10 feet of solid limestone at the bottom of the quarry (No. 60). The plant is equipped with a Wheeling Mold Company crusher and crushed lime is furnished to the farmers and through the season the plant can not supply the demand.

	No. 74	No. 79	No. 78	No. 64	No. 60
Silica	5.46	18.98	5.33	7.77	1.90
Lime carbonate	91.07	67.80	92.35	87.89	95.00
Magnesium carbonate	0.59	6.31	1.42	3.49	1.80
Iron and alumina	2.08	5.67	1.28	0.81	1.20
Loss on ignition	0.29	0.98	.....	.....	.....
	99.49	99.74	100.38	99.96	99.80

The second plant of Mr. Wheeler's is further up the ridge and has two pot kilns and a Scott clay pulverizer for making crushed lime, and the kilns will make about 800 bushels of lime daily. At the new quarry here there is about 8 feet of cover and 4 to 6 feet of limestone exposed (No. 59), but this does not represent the thickness of the limestone. The stone at the upper quarry is bluish-gray color, very granular in texture with calcite stringers, plates, and crystals. The limestone is coarsely crystalline and sparkles in the sunlight due to the numerous crystal plates, and it is quite fossiliferous. At the lower quarry the structure of the stone is similar, but the color is darker and in places almost black.

Near the northern end of Ferrel Ridge just east of Butts Store on Tilhance Creek in the branch run valley are good exposures of the Helderberg Limestone full of fossils. The lower portion of the outcrop is a dark slaty gray limestone very compact and quite hard with but few fossil shells but large numbers of coral masses (No. 52). The upper ledges are coarse granular bluish-gray color, full of calcite plates, and very fossiliferous (No. 53). The upper portion contrasts strongly with the lower hard compact ledges and on analysis is found to be a purer limestone. The stone has been blasted out to make the road, and it would prove a valuable road material for this whole area.

Through the upper ledges occur beds of black flint in rhomboidal small blocks translucent in thin pieces. The weathered slopes of the hills along this outcrop show large quantities of this flint or chert which is very brittle and breaks in small angular blocks.

To the west of Tomahawk in the gap through Ferrel Ridge, the Oriskany Sandstone and the Helderberg Limestone are exposed in the walls of the ravine and they form cliffs on the north wall of the road. A short distance west of Tomahawk just beyond the Oriskany contact, the limestone appears to be quite siliceous and the analysis shows this to be true (No. 55).

This rock is a gray granular limestone with small cleavable plates of black calcite also calcite stringers and crystals. In some of the ledges minute globular masses of bluish vitrecus quartz occur, but these were omitted from the sample analyzed, otherwise the silica would have run much higher. The limestone is quite fossiliferous and it dips 26 degrees southeast. At this place a small quarry was opened for stone for the road and it is about 1,000 feet west of the big spring at Tomahawk which is near the contact of the Oriskany and the Marcellus-Hamilton Shales.

About 300 feet further west the limestone ledges are quite solid and bluish-gray in color, weathering to a cobbly surface (No. 56), and the analysis shows it to be a purer rock than the last and quite similar to the outcrop east of Butts Store, and both outcrops are near the base of the Helderberg and not far from the contact with the underlying Bossardville Limestone. A small lime plant back of Ridge Store, 14 miles south of Berkeley Springs, makes a good grade of lime from the Helderberg Limestone on west slope of Warm Spring Ridge (104):

	No. 59	No. 52	No. 53	No. 55	No. 56	No. 104
Silica	5.08	5.77	4.41	10.28	5.32	6.24
Lime carbonate	92.55	88.61	93.63	87.54	89.38	88.57
Magnesium carbonate	1.34	2.69	1.44	1.29	2.25	2.46
Iron and alumina	0.95	2.54	0.78	0.95	2.43	2.51
	99.92	99.61	100.26	100.06	99.38	99.78

These various limestones of the eastern Panhandle Area are lost sight of in the consideration of the mineral resources as they are so far overshadowed by the exceptional value of the low silica limestones of the Martinsburg and Millville

PLATE XXVIII—Conococheague Limestone near Potomac River on New Line of Williamsport, Nessle, and Martinsburg Railroad.

districts with their large quarries. If the western and interior counties of the State had these so-called minor limestone deposits of the eastern Panhandle they would be considered very fortunate.

Here is a wealth of material for good roads, well distributed in area, valuable for lime for farm fertilizer with resultant increased yields through the years that would be hard to estimate in dollars. There is a great reserve of such material that should be brought into use not by large and costly lime and crushing plants, but by numerous small crushers and lime-kilns to supply the trade through a radius of several miles around the quarries. These small farm fertilizer and road material crushers are now made by a number of machine companies. They are light and portable and can be bought at low prices and yield good profits.

In this Chapter these limestone deposits have been described here and there over the area to illustrate the possibilities, but the number of possible and favorable locations for development is large, and the distribution of these limestones in parallel belts not many miles apart will enable all portions of the area to be supplied at low cost with good roads and good agricultural and building lime.

CHAPTER XV.

GENERAL AND CHEMICAL DESCRIPTION OF THE LOW SILICA FLUXING LIMESTONE BELTS IN BERKELEY AND JEFFERSON COUNTIES.

The low silica limestones of the Martinsburg area have long been held in high favor by the iron and steel manufacturers in the territory reached under low freight rates from this district. The steel companies have sent their engineers and chemists to this field from time to time to examine and test the deposits in many different places. Large numbers of analyses have been made, and many of these have been placed at the disposal of the writer by these companies and by individual landowners. Also a large number of analyses of typical outcrops have been made in the State Geological Survey laboratory.

The low silica fluxing limestones are found in the Upper Stones River Formation in this area, and the outcrops of this limestone are usually low in silica and high in carbonate of lime, and the quarry industry centers in these belts. No other formation is quarried for fluxing stone in these two counties, except the Millville low silica dolomites, though large lime and ballast quarries are located in other limestone formations in this area.

None of the other limestones will probably ever be worked for fluxing stone, unless the fairly high-grade limestone belts found in the Beekmantown should later find a market. Some of these belts resemble in appearance the Upper Stones River, but the silica runs two to three times higher. A few of these

Beekmantown belts will be described to illustrate their character, before the general discussion of the Stones River.

BEEKMANTOWN LIMESTONE BELTS.

The Beekmantown Limestones, as a rule, are high in silica and magnesia, but through the formation are belts of fairly pure limestone which are held in high favor by the owners and regarded by them as the same limestone as quarried near Martinsburg, and they are often claimed to be as pure limestone and as low in silica; but in most cases, unfortunately, the percentage of silica is found by analysis to run high for an open-hearth flux.

Along the Potomac River east of the mouth of Opequon Creek at Whitings Neck, the limestone bluffs for a distance of 2,000 feet east, and the same distance west of the north-and-south county road, are composed of a light-cream to dove-colored limestone, breaking with smooth fracture, and having every appearance to the eye of the typical low silica limestone of the Upper Stones River. This limestone, however, is associated with the typical Beekmantown cherts, and its relations to the surrounding strata all show it to be Beekmantown, far above the average purity for this group but still fairly high in silica. This deposit has long attracted attention and has been carefully tested.

A series of chemical analyses was made along these bluffs for a distance of 4,800 feet, starting at this distance west of the north crook of the river road on Whitings Neck, and ending at this point. These analyses are grouped in figure 18. The figure represents a continuous section, but is broken on the sheet into four lines for convenience in space. The surface level of this area is almost a smooth plain above the river, 400 feet above sea-level.

These limestones are not low enough in silica for open-hearth steel fluxing stone, though to the eye they resemble so closely the Martinsburg quarry rock. This locality has long been cited as one of the greatest and most valuable deposits of high-grade, low silica limestone in the district. As

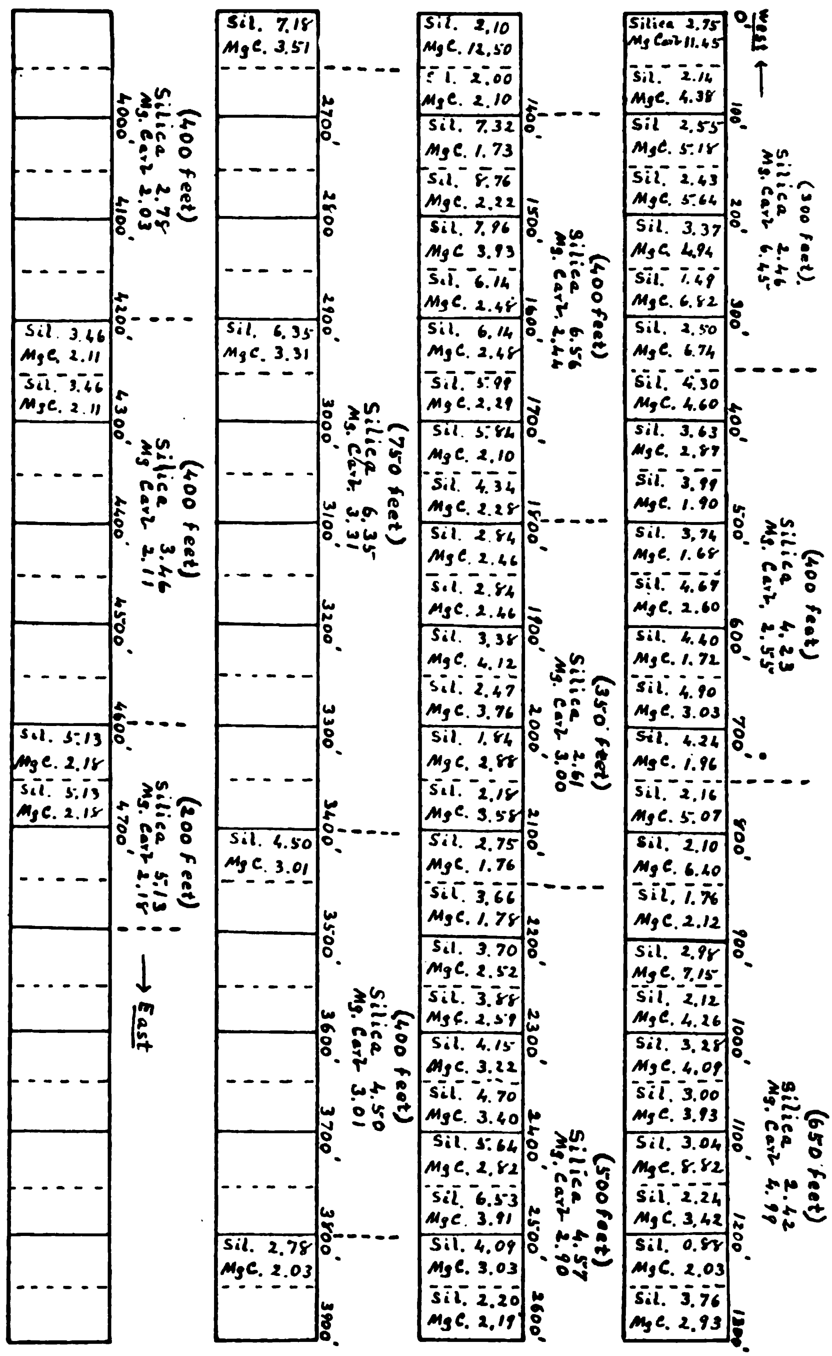

Figure 18. Diagram Cross-Sections showing the chemical composition of the Beekmantown Limestone along Potomac at Whitings Neck.

a blast-furnace flux, it would compare favorably with the Tyrone and Hollidaysburg, Pennsylvania, districts, which supply a large quantity of flux to the Pittsburgh furnaces; and it would probably also burn into a very fine grade of lime.

In this limestone belt, as illustrated in the figure sketch, the first 350 feet at the west averages 2.46 per cent. silica, and 6.45 per cent. magnesium carbonate; the next 400 feet averages 4.23 per cent. silica and 2.55 magnesium carbonate; the next 650 feet averages 2.42 silica and 4.99 magnesium carbonate; the next 400 feet averages 6.56 silica and 2.44 magnesium carbonate; the next 350 feet averages 2.61 silica and 3.00 magnesium carbonate; the next 500 feet averages 4.57 silica and 2.90 magnesium carbonate. Analyses were only made here and there through the rest of the section. These results may be placed in tabular form for the 4,800-foot length of sampled outcrop from west toward the east:

Feet.		Silica	Magnesium Carbonate
0 to 350		2.46	6.45
350 to 750		4.23	2.55
750 to 1400		2.42	4.99
1400 to 1800		6.56	2.44
1800 to 2150		2.61	3.00
2150 to 2650		4.57	2.90
2650 to 3400	(No. 23)	6.35	3.31
3400 to 3800	(No. 22)	4.50	3.01
3800 to 4200	(No. 21)	2.78	2.03
4200 to 4600	(No. 20)	3.46	2.11
4600 to 4800	(No. 19)	5.13	2.18
Average		4.10	3.18

The north-and-south county road is at 2650 feet in the above table, and the complete analyses of the limestone east of this road, as made in the Survey laboratory, are given below. The location and width of outcrop of each sample are shown in the figure sketch:

	No. 19	No. 20	No. 21	No. 22	No. 23
Silica	5.13	3.46	2.78	4.50	6.35
Lime carbonate	91.73	94.21	95.41	92.40	90.14
Magnesium carbonate	2.18	2.11	2.03	3.01	3.31
Iron and alumina	0.85	0.35	0.34	0.44	0.35

A few complete analyses were made of the limestone west of the road. No. 24 was taken over 50 feet of outcrop about

500 feet west of the road, and would come in the section of the sketch at about 2150 feet. No. 25 was taken 600 feet further west and would correspond above to the 1400—1800-foot interval. No. 26 was taken within the 350—750-foot interval, while No. 27 is from near the beginning of the section at the west end. The samples were all taken from apparently high-grade ledges that looked like low silica limestone:

	No. 24	No. 25	No. 26	No. 27	No. 28
Silica	3.42	6.31	3.10	1.99	45.78
Lime carbonate	91.84	88.65	94.80	96.14	49.23
Magnesium carbonate	4.89	5.07	2.29	2.16	2.68
Iron and alumina	0.36	0.49	0.26	0.24	2.83

The ledge sampled in No. 27 is a dark-gray, somewhat granular limestone which carries small siliceous limestone concretions, flattened parallel to the bedding-planes. These silica balls are light-gray in color, of higher gravity than the limestone, and are quite crystalline. They look like a mixture of flint and limestone, as the crystalline portion is quartz. The analysis of these concretions is given as No. 28 above.

This belt of rather pure Beekmantown Limestone can be traced south for a mile and a half, and through this distance has every appearance to the eye of a low silica limestone. It is well exposed on the county road leading south, especially at the run crossing, and then can be traced east across the fields. It is also found here and there across the fields to the south.

While these limestones are found at a number of places in the Beekmantown, only one more illustration will be given, taking a belt in Jefferson County between Leetown and Charlestown, which also has every appearance of a high-grade belt of low silica limestone, 300 to 400 feet in width and a length of over a mile, and which can be traced by separate outcrops for several miles. It has been tested a number of times and shows a very good grade of limestone for many purposes. It is, however, too high in silica for use in open-hearth steel.

The following analyses were made of this limestone in the Survey laboratory in 1906. No. 202 was the dark-blue, almost black limestone east of the good belt. No. 206 was from near the east edge of the belt, and a light-gray rock. No. 204 was darker-gray in color and about 100 feet west of the last. No. 207 was from the east side of the belt, but further south than the other samples. Still further south, sample No. 205 was taken. No. 203 was collected on the little hill about the center of the belt. No. 209 is a dark, very irregular limestone at the west edge of the belt:

	No. 202	206	204	207	205	203	209
Silica	4.20	2.00	3.50	2.30	1.60	2.00	6.70
Lime carbonate	94.34	96.10	92.97	94.92	93.36	95.90	78.46
Magnesium carbonate	0.98	1.51	1.83	2.12	4.54	1.51	17.64
Iron and alumina..	0.80	0.70	1.46	0.90	0.60	0.60	2.80
	100.32	100.31	99.76	100.24	100.10	100.01	99.50

More recently this tract was tested by a long trench across 325 feet of width of the better portion of the belt, and samples were taken from 10 to 16 feet apart, and the results are given in the following table. The analyses were made by an outside company which made the trench and examination, and the results were kindly given for this report:

Sample	Silica	Magnesium Carbonate
1	2.80	3.60
2	1.40	2.25
3	4.92	27.45
4	1.22	3.00
5	1.20	2.55
6	1.70	1.80
7	2.00	1.95
8	3.70	4.05
9	2.60	4.80
10	1.64	1.50
11	2.10	8.25
12	5.90	12.24
13	3.90	1.50
14	4.30	5.51
15	4.54	2.25
16	8.00	23.32
17	8.30	14.40
18	2.86	17.31
19	4.16	3.19
20	1.05	1.05
21	3.12	1.62
Average	3.40	6.84

If the ledges Nos. 16 and 17, twenty feet in width, be eliminated, the average silica for the 305 feet would be 2.90, and 5.57 per cent. magnesium carbonate. This belt shows lower silica than the one on the river. It is not an open-hearth stone, but might be valuable for blast-furnace flux, or for lime, and by separation of the high magnesium ledges would be valuable for Portland cement. Another belt of this limestone is found near the lanes one mile north of Kearneysville near the railroad.

East of the Stones River Limestone north of the north branch of the Shepherdstown road, a half mile north of Van Clevesville and near the railroad, there is a belt of low silica limestone with a width of 300 feet that is usually regarded as the same horizon as at the Martinsburg quarries. The limestone resembles the Stones River, and it is but a short distance east of that outcrop. Its relation in dip and position to the Beekmantown further east appears to correlate it with that formation.

The following analyses were made on samples across the 300 feet of outcrop, and were taken by one of the steel companies which made an examination of the surface outcrop only. The samples represent 30-foot intervals and were taken from east (No. 1) to west:

	No. 1	No. 2	No. 3	No. 4	No. 5
Silica	0.68	0.88	1.10	1.38	0.66
Lime carbonate	96.99	96.42	94.36	95.67	97.16
Magnesium carbonate	1.53	1.23	3.33	1.92	1.80
Iron and alumina	0.92	0.94	0.82	0.68	0.74
Phosphorus	0.007	0.008	0.005	0.005	0.006
Sulphur	0.025	0.047	0.017	0.041	0.025

	No. 6	No. 7	No. 8	No. 9	No. 10
Silica	0.26	1.78	0.52	3.86	2.06
Lime carbonate	96.98	95.75	96.99	92.50	91.94
Magnesium carbonate	1.86	1.44	2.02	1.34	3.78
Iron and alumina	0.60	0.80	0.64	1.96	1.34
Phosphorus	0.003	0.006	0.004	0.005	0.003
Sulphur	0.117	0.094	0.083	0.017	0.143

This is a very pure belt of limestone according to the surface tests, and by care in location of quarries should prove valuable, but further and deeper tests should be made. Its nearness to the railroad adds much to its value. It can be traced over a length of nearly a mile, and varies in width from

300 to 400 feet. If this outcrop could be worked to a depth of 100 feet, there would be available approximately 15,000,000 tons of limestone.

Another belt of very good limestone in the Beekmantown Formation is found just east and southeast of Darkesville Station on the Cumberland Valley Railroad. This stone in its physical appearance resembles the Upper Stones River Limestone very closely. The following analyses show its composition. No. 187 was made in the Survey laboratory from sample taken at the lane leading from the main road a short distance east of the station, while the other analyses were made by an outside company from samples taken a half mile south:

	No. 187	"A"	"B"	"C"	"D"	"E"
Silica	1.67	1.32	0.80	1.10	2.10	3.00
Lime carbonate.......	96.85	96.20	97.60	97.10	95.70	93.70
Magnesium carbonate.	1.20	1.87	0.99	1.13	1.22	1.43
Iron and alumina.....	0.20	.....	.....	.....	.....	.....

UPPER STONES RIVER LIMESTONES.

The most important fluxing limestone in Berkeley and Jefferson Counties, outside of the Millville Dolomites, is the low silica and high carbonate of lime rock in the Upper Stones River Formation, now so extensively quarried around Martinsburg. These limestones are found in belts with a northeast-southwest trend, and with varying widths of outcrop. The ledges are usually tilted at rather high angles, so that vertical quarry-faces in this rock at a certain depth pass through the high-grade into a lower-grade limestone. The workable depth of the quarry depends on the thickness of this upper, low silica limestone, and on the amount of dip.

In order to show the character of the limestone below the surface, the records of three diamond well drill cores to a depth of 200 feet are given with their chemical analyses. It must be borne in mind that these rocks dip at high angles, and that the vertical core does not represent one stratum but intersects the various ledges and probably near the bottom cuts into the underlying Beekmantown Limestone. It does represent the future character of the quarry which is excavated down nearly vertical and so gives the practical composition of the rocks below the surface. Only the lime carbonate was determined in the short lengths of core while complete analyses were made of larger sections of the core. The percentage of lime carbonate is less toward the bottom than near the top. The results of the tests are shown in figure 19, where the record is drawn to scale and the lime carbonate percentages marked thereon, and the group sections for complete analyses are indicated. A study of this diagram with its analyses shows the varying character of the different ledges. Section "A" was near the center of the belt while section "B" was near the border of the belt and the drill soon passed below the low silica limestone and it shows a close agreement in analyses and indicates that the rock is a dolomite below the surface which is further proved by the group analysis of this portion but the silica runs high for a good fluxing dolomite. The banded segments represent clay seams and pockets, and in the first section some caves or caverns were encountered.

The limestone in these cores was analyzed in groups as indicated in the figure and the results were as follows:

Bore Hole "A" (204 Feet).

	A(16')	B(12')	C(9')	D(28')	E(40')
Silica	1.22	0.96	2.64	6.78	5.88
Lime carbonate	96.85	96.89	96.03	85.39	87.60
Magnesium carbonate	1.30	1.60	0.90	5.40	5.40
Alumina oxide	0.26	0.32	0.16	1.53	0.65
Ferric iron oxide	0.32	0.22	0.22	0.89	0.45

This record shows a low silica down for almost 100 feet and also low magnesia. Below that depth the silica is high for fluxing stone and the magnesia has also increased. The amount of iron and alumina is low in the whole core.

Bore Hole "B" (200 Feet).

	A(3' 9")	B(9')	C(18')	D(130')
Silica	2.60	2.61	3.48	4.60
Lime carbonate	89.00	93.93	58.53	54.32
Magnesium carbonate	8.90	4.48	37.41	39.42
Alumina oxide	0.65	0.61	0.57	0.54
Ferric iron oxide	0.45	0.45	1.01	1.12

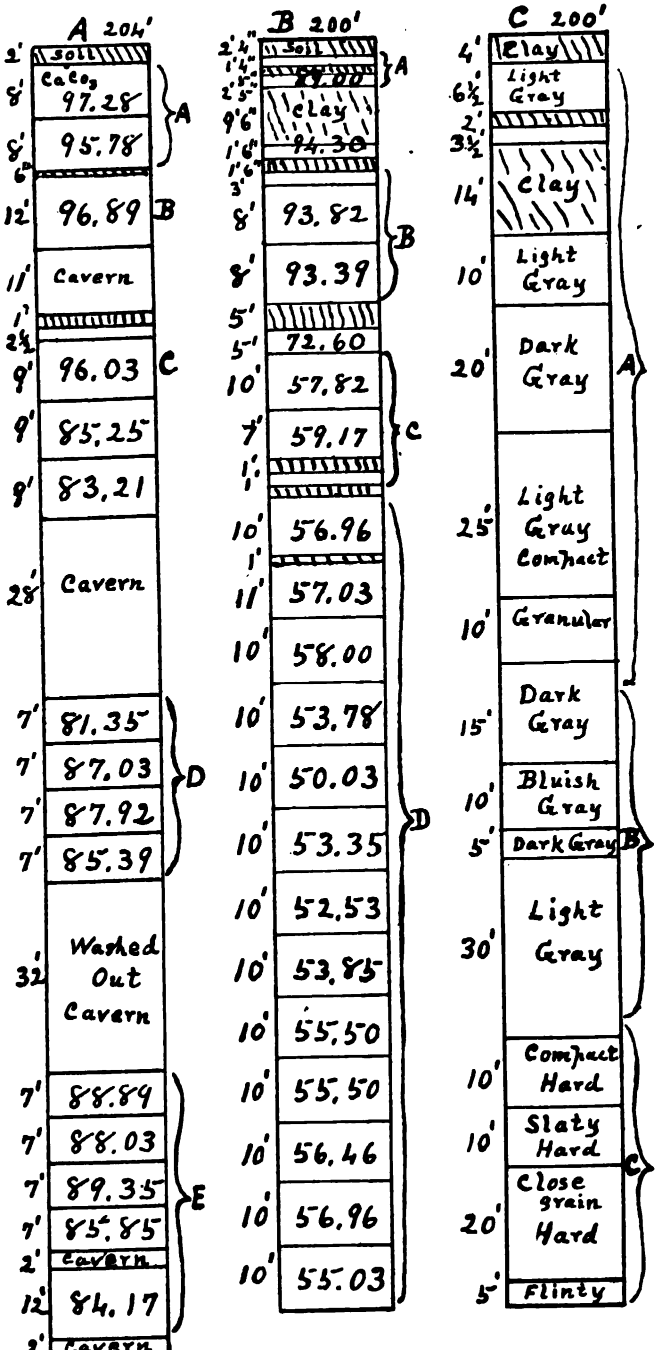

Figure 19. Diagram Sections of Bore Holes in Upper Stones River Limestone near Martinsburg.

In this boring near the edge of the belt, the silica is high from the surface down and the lower rocks are almost typical dolomites except for the high amount of silica. The iron is much higher near the base and the percentage there is high for these limestones.

Bore Hole "C" (200 Feet).

	A(100')	B(50')	C(50')
Silica	0.63	1.82	5.83
Lime carbonate	96.90	93.01	53.78
Magnesium carbonate	1.66	4.24	38.38
Iron and alumina	0.77	0.98	1.56

In this core the rock averages good to 150 feet, but the low silica stone is probably 130 feet deep. At the bottom again is the high silica but otherwise almost true dolomite rock. There is a close resemblance in the chemical composition of the dolomite rock at base in holes "B" and "C", though these are several miles apart. A study of these records shows that it is difficult to estimate the depth of the low silica limestone in estimating the future supply of stone for quarry work. In the center of the belts is a good depth amounting to probably 120 to 130 feet, but near the edge of the belt on the side away from the dip direction the belt is shallow and increases toward the direction of dip. For purposes of estimates of tonnage the increasing depth toward the direction of dip is regarded as compensating the shallow depth on opposite side and estimates may be made in approximation by assuming the depth of working at around 120 feet. Borings, however, show all sorts of modifying conditions due to folding of the rocks and faulting, etc. In some borings the depth of rock at center of belt is only 30 to 40 feet and again with overturned folds, shales are found at depth of 20 to 50 feet under the limestone. These conditions are regarded as exceptional and are disregarded in total estimates where the shallowing of the rock is unknown. Estimates made in this Chapter, then, are to be taken as approximate only, and they were made to give some idea of the large amount of tonnage of this valuable low silica limestone available in these eastern counties.

A few cross-sections of these belts will be given to show their character and chemical composition. One of the Berkeley County belts was traced across the Potomac River into Maryland, and there was tested by one of the steel companies over a width of 900 feet east and west. The results of this work are shown in figure 20, where 0 feet represents the west end of the section. On the west is a belt of magnesian limestone, 500 feet wide on outcrop, which averages 2.39 per cent. silica, 75.33 per cent. lime carbonate, 21.28 per cent. magnesium carbonate. In some of the ledges for a distance of 150 feet, this rock is a true dolomite with about 35 per cent. magnesium carbonate, but over three per cent. silica.

Next to the east is a belt of low silica high-grade limestone, 225 feet wide, which averages 0.72 per cent. silica, 94.77 per cent. lime carbonate, 3.47 per cent. magnesium carbonate, which represents a valuable fluxing stone low in silica and magnesia. East of the high-grade belt is a belt of low silica dolomite, but it is also low in magnesium carbonate for a good dolomite. It averages 0.99 per cent. silica, 79.80 per cent. lime carbonate, and 17.57 per cent. magnesium carbonate. East of this belt is the high silica more or less magnesian limestone.

In the Martinsburg area the low silica limestone is found on a number of different tracts and has good length and width of outcrop. On one of these tracts chemical analyses were made every 20 feet across the outcrop and the results are shown in figure 20.

The average composition across the 420 feet of outcrop is 0.53 per cent. silica, 0.27 per cent. alumina, 94.21 per cent. lime carbonate, and 4.73 per cent. magnesium carbonate. This is a remarkable outcrop in its high degree of purity for this width of belt. The same belt was examined further north in a similar manner and the results are shown in figure 20, but the silica in this section is higher. The average composition of the 450 feet of outcrop it 1.37 per cent. silica, 94.54 per cent. lime carbonate, 2.57 per cent. magnesium carbonate, with 0.74 per cent. iron oxide, and 0.52 per cent. alumina.

In this same tract there is a second belt 250 feet wide as shown in the above figure which averages 1.13 per cent. silica,

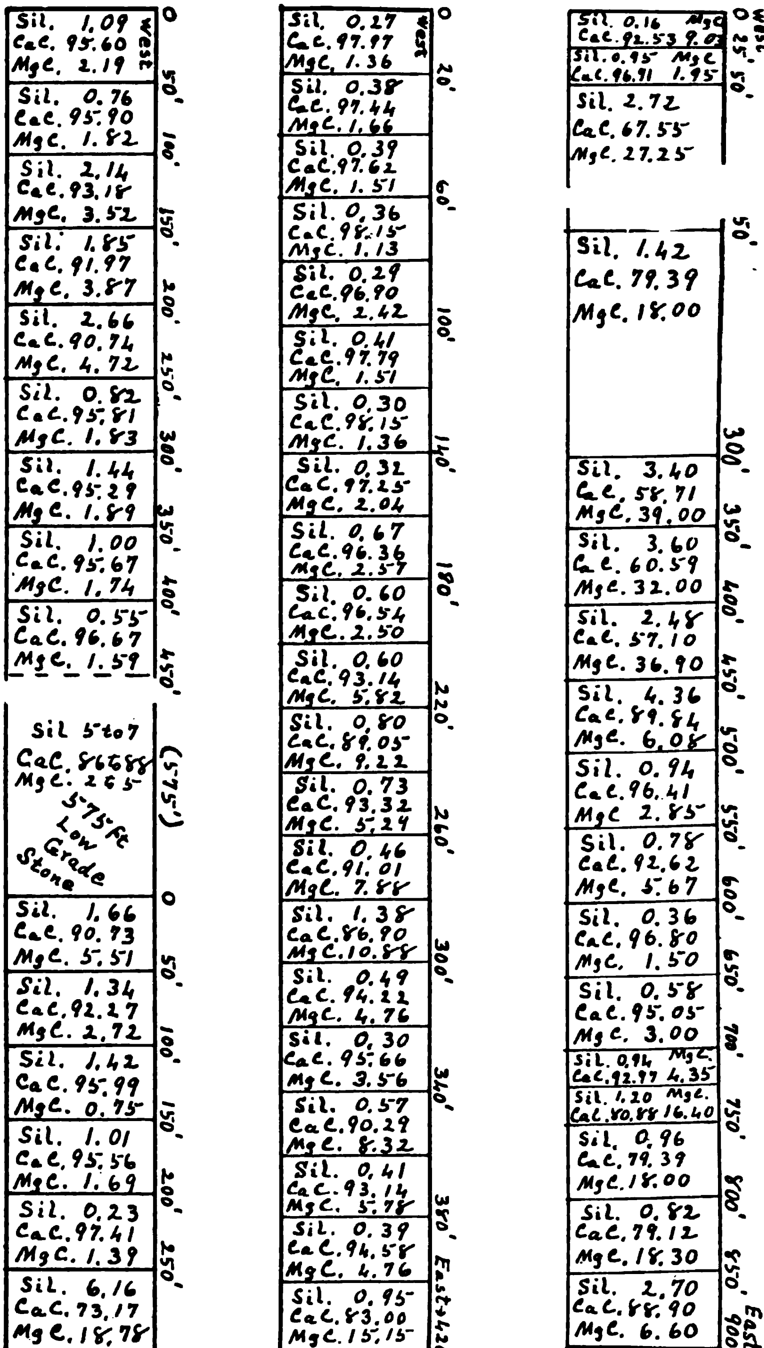

Figure 20. Diagram Cross-Sections showing chemical composition of Stones River Limestone in Martinsburg District.

94.39 per cent. lime carbonate, 2.41 per cent. magnesium carbonate, with 1.53 per cent. ferric iron, and 0.39 per cent. alumina. The average amount of phosphorus in the 450-foot belt is 0.01 per cent., and in the 250-foot belt it runs 0.009 per cent., while the sulphur runs 0.11 and 0.14 per cent. The average composition of the two belts is very similar. The 250-foot belt is probably the same as the preceding one described from further south. The continuation of the 450-foot belt to the south with an average of 32 analyses shows an average composition at the south of 1.38 per cent. silica, 97.22 per cent. lime carbonate, 4.52 per cent. magnesium carbonate, with 0.39 per cent. alumina.

LOW SILICA LIMESTONE BELTS NEAR MARTINSBURG.

A description of the different belts of low silica limestone of the Upper Stones River Formation in the Martinsburg district will now be given with chemical analyses, arranged according to the following outline:

- Martinsburg Quarry Belt.
    - Indian Church Division.
    - Security-Standard Division.
    - West Quarry Division.
    - Darkesville-Bunker Hill Division.
- Falling Waters Belt.
    - West of Falling Waters.
    - East of Falling Waters.
- National Belt.
- Blair Belt.
- Opequon Belt.
- Leetown-Van Clevesville Belt.
- Whitings Neck Belt.

Martinsburg Quarry Belt.

INDIAN CHURCH DIVISION.—In the northern portion of Berkeley County on the Potomac River at the so-called Indian Church and the Sun and Moon Spring, three miles west of Williamsport, Maryland, and the same distance north of Falling Waters on Millers Bend of the River, is a high cliff of the low silica limestone of the Stones River Formation which for purposes of description will be called the Indian Church Belt.

This belt has a trend N. 24° E., and outcrops to the river and again in Maryland west of Pinesburg Station on the Western Maryland Railroad, thence north nearly to the Pinesburg county road where it appears to dip under the higher silica limestone. In Maryland near the railroad it is 225 feet wide and near the Indian Church it is 250 to 300 feet wide. The belt extends southward over half-way to the Prospect Hill road but here becomes quite narrow and dips under the high silica stone. Its length in West Virginia is about three miles and its width varies from 275 feet to about 40 feet at the south end. The limestone forms a vertical wall cliff following the river parallel to the strike of the rock for a distance of nearly a half mile with a height of 160 to 175 feet with a narrow shelf next to the river, and over part of the distance the cliff extends to the water's edge.

The limestone varies in color from light-gray or dove-color to a bluish-gray and even black rock in certain ledges. The dip of the formation is about 50 degrees east and apparently north, but at this place there is a sag or synclinal bend in the strata parallel to the strike. The ledges outcropping up this cliff vary in texture, color, and chemical composition. Some of the ledges are slaty, others very compact and hard, while others are quite granular. The stone blasts out in large angular blocks and most of it is quite brittle. Certain ledges carry fossil gasteropods and shells of brachiopods which correlate this portion of the limestone with the Middle Stones River Formation. Some of the ledges are very low in silica while others run as high as 2 per cent. The lime carbonate varies from 91 to nearly 99 per cent. The average of a large number of analyses made by some of the steel companies is about 1.5 per cent. silica for the cliff exposure.

This tract at the river is now controlled by the Pittsburgh Limestone Company, a subsidiary organization of the Carnegie Steel Company, which has opened a number of quarries along the cliff, graded for track and plant, and laid quarry

PLATE XXIX.—Crushing Plant of the National Limestone Company South of Martinsburg.

tracks. The company plans to work to an average output of a million tons a year, or 60 to 70 cars a day. The property is reached by a branch from the Western Maryland Railroad from Charlton, crossing the river about a half mile above the quarry. The track was completed to the river on the Maryland side and the bridge piers completed in 1914 and part of the grade completed on this side, and completed to the quarry in the fall of 1915.

Chemical Composition.—The following analyses of this limestone were made by the late Mr. S. W. Shoop, of Altoona, in 1905:

	No. 1	No. 2	No. 3	No. 4
Silica	0.25	0.17	0.19	0.25
Lime carbonate	73.20	98.85	95.10	98.60
Magnesium carbonate	21.65	.....	3.85	.....
Alumina	4.90	0.98	0.86	1.15

No. 1 was of the dolomite forming the east wall of the high-grade belt.
No. 2 was at back end of cavern at Indian Church, 150 feet from face of cliff.
No. 3 was an average of ten samples taken along the cliff.
No. 4 was of the pure limestone near the Sun and Moon Spring.

The following group of analyses was made by Mr. J. B. Krak in the laboratory of the West Virginia Geological Survey of samples collected by the writer in the summer of 1914, and the locations of analyses are shown on the accompanying map of the low silica limestone belts from the Potomac River to the Virginia Line:

	No. 9	No. 2	No. 4	No. 7	No. 12
Silica	1.45	0.92	1.10	1.90	1.37
Lime carbonate	95.98	97.05	98.25	96.20	91.66
Magnesium carbonate	2.02	1.64	0.77	1.85	6.16
Iron and alumina	1.45	0.83	trace	0.53	0.71
	100.21	100.44	100.12	100.48	99.90

No. 9 was of sample taken 300 below the Sun and Moon Spring and represents about 20 feet vertical of the cliff.
No. 2 was at Sun and Moon Spring and represents about 25 feet vertical on above that of No. 9.
No. 4 was taken near west end of quarry, but east of the contact of the low and high silica stone.
No. 7 was taken at top of the high cliff above No. 4.
No. 12 was about a half mile west of the quarry and in Beekmantown Limestone which is here fairly pure.

These analyses show a high percentage of lime carbonate and low magnesia, but a higher percentage of silica than the Shoop samples. By sampling only the high-grade ledge, the silica would run very low, but sampling vertically across the ledges to secure an average, the silica runs higher. The average silica is, however, under one and a half per cent. which, with the favorable conditions for quarry work in the high vertical cliffs, makes the property a very valuable one.

If an estimate be made on the tonnage of this belt with an average width of 225 feet, length of two and a half miles, and vertical depth of 150 feet, there would be available nearly 35,000,000 tons of low silica limestone in the Indian Church Division.

SECURITY-STANDARD DIVISION.—The Indian Church Division quarried by the Pittsburgh Limestone Company is faulted near the Prospect Hill road, and dips under the higher silica stone of the Chambersburg Formation. On the western side of the fault, it comes to the surface a halt mile south of this county road, and the outcrop is then practically continuous south to the Security quarries, and on south to beyond Martinsburg where it is quarried by the Standard Limestone Company.

The low silica limestone of this division outcrops in a narrow belt on the lane to the south of the Prospect Hill road. It has a width of 300 feet on the road leading west from Falling Waters, and about a mile west of this town. Its course is north 24 degrees east and it dips east at an angle of 70 degrees. The outcrop can be followed south across the next two west roads, and it crosses the Williamsport Pike just north of Hainesville with a width of 200 feet, and then continues south to Security.

The limestone is light-gray to dove-color, breaking with a smooth, conchoidal or shelly fracture, and resembles all the way the Martinsburg quarry rock. The outcrop follows small run valleys which have been carved in the more soluble rock of this formation. The belt is thus depressed below the surrounding country as a rule. No large cliffs are exposed, so that not over ten or fifteen feet vertically can be examined, but a series of ledges can be observed as the outcrop is followed down the hill to the runs.

The larger portion of this outcrop west and southwest of Falling Waters is owned by two limestone companies, the Standard Lime and Stone Company and the J. E. Baker Lime Company, though no development has taken place, and no openings are made on the belt. As far as known, the belt has not been drilled or tested below the surface. It is located about a mile from the Cumberland Valley Railroad, while the new Railroad,—Williamsport, Nessle, and Martinsburg—will pass close to the outcrop.

Chemical Composition.—Two samples of this limestone belt were taken on the road west from Falling Waters, and one sample was taken just west of the belt to show the change in composition at this line. No. 32 was taken at the east edge of the belt. No. 34 is from about the center of the belt and just south of the county road about 100 yards; while No. 33 is from the ledge just west of the belt of high-grade stone, and it is not far from the Beekmantown contact:

	No. 32	No. 34	No. 33	No. 42	No. 46
Silica	1.52	1.49	3.67	0.72	0.80
Lime carbonate	97.01	93.80	87.63	97.95	98.14
Magnesium carbonate	1.62	4.37	8.79	1.44	1.08
Iron and alumina	0.27	0.42	0.31	0.18	0.25

The limestone was not sampled on the next road to south, but its characters are very similar, and analyses made here would probably duplicate those given above. On the next road south, or the first east-and-west road north of Nipetown, this belt was sampled in No. 42, and shows a very pure limestone. The next outcrop of this belt sampled was just east of the pike at Hainesville, No. 46, which still shows a very high-grade limestone.

A mile south of the Hainesville outcrop are the quarries and large plant of the Security Lime and Cement Company, described in the preceding Chapter. Samples were taken from these quarries and analyzed in the Survey laboratory with the following results:

Silica	0.49	1.07	1.14
Lime carbonate	97.96	89.66	95.18
Magnesium carbonate	2.01	8.98	3.47
Iron and alumina	0.36	0.55	0.81

In these quarries the low silica limestone is quarried and shipped for flux, while the other stone is available for ballast. A large amount of lime is also made at this plant. The last two samples were taken on the vertical face of the quarry across a number of outcropping ledges, while the first sample represents the high-grade fluxing stone in these quarries. This belt of low silica limestone outcrops in the cuts of the railroad just south of the Security quarries with a width of 200 feet.

In estimating the tonnage of this belt north of the railroad from Cumbo to the Cumberland Valley at Berkeley Station, north to a mile south of the Prospect Hill road, the average width is taken as 200 feet, and length would be five and a half miles; so that with a working depth of 100 feet, there would be about 46,500,000 tons of low silica limestone.

This belt of low silica limestone can be traced south, crossing the Cumberland Valley Railroad just north of the county road leading east to the Opequon at Eagle Schoolhouse. It can be followed to the old McDowell lime quarry in North Martinsburg east of the Williamsport Pike. This quarry was opened in 1873 to supply stone for a six-foot draw-kiln that was operated for 35 years, but is now abandoned. This belt follows just east of Water Street in Martinsburg, and at the south edge of town connects with the line of abandoned quarry holes, and then the working quarries of the Standard Lime and Stone Company.

At their furthest south quarry, to the north of Evans Run, this limestone dips south and passes under the Chambersburg Limestone. In these quarries the width of outcrop was 200 to 250 feet, with the Middle and Lower Stones River to the west. On the east, the Upper Stones River Limestone dips east under the cobbly Chambersburg, the contact being very sharp in these quarries.

The length of this portion of the outcrop from the south end of the Standard quarries north to the railroad south of Security quarries is six miles. Assuming an average width of 200 feet and a working depth of 100 feet, there would be 50,688,000 tons of low silica limestone in this portion of the belt, though a considerable tonnage has been removed in the two miles of Standard quarries.

If the average depth of these quarries be taken as 50 feet which is conservative, as one quarry was worked to a depth of 90 feet, there would be removed in the two miles about 8,500,000 tons, which is about the tonnage in the west quarry belt on this property, so that in the estimate of tonnage this removal can be neglected. It must be kept in mind that these estimates on tonnage are based on somewhat doubtful data of continuity of the belt, average width, and probable working depth; and they are only made to afford an approximate idea of the value of these deposits to this county.

The Standard Lime and Stone Company operations are the oldest and largest in this portion of the State, and their quarries and plants are described in the preceding Chapter. The limestone is low in silica and high in lime carbonate, and it has proved most satisfactory to the trade. The following analyses of this limestone from the Standard quarries were made in the Survey laboratory from samples taken ten years apart:

	1905	1915
Silica	0.60	0.51
Lime carbonate	95.44	98.33
Magnesium carbonate	2.51	0.78
Iron and alumina	0.69	0.34
Phosphorus	0.05	.....
	99.29	99.96

This belt of low silica limestone dips under the Chambersburg and disappears from the surface just north of Evans Run. A short distance south of the run in a deep hollow on the Tabb farm, owned by the National Company, this belt outcrops again for a few hundred yards, and then is covered by the Chambersburg Limestone on the higher ground to the south. An analysis was made of this outcrop, No. 212. The belt again comes to the surface on the Clohan and Michael farms just south of the cross-road that leads east from Pikeside. The belt now has a width of 225 to 250 feet with the Beekmantown Limestone on the west, and the Chambersburg on the east. An analysis was made of this limestone on the Michael farm, owned by the National Limestone Company, No. 183. On the next farm south, known as the Fulk farm, another sample was taken and analyzed, No. 211:

	No. 212	No. 183	No. 211	No. 185	No. 184
Silica	0.35	1.50	0.71	0.23	0.74
Lime carbonate	98.87	95.59	98.94	98.78	97.32
Magnesium carbonate	0.89	2.77	0.95	0.73	1.87
Iron and alumina	0.11	0.32	0.12	0.15	0.30
	100.22	100.18	100.72	99.89	100.23

This belt is found 500 feet east of the Winchester Pike opposite the road west to Tablers Station. Here on the Stewart farm, it is 200 feet wide on outcrop and well exposed. Its composition at this place is shown in No. 185. A synclinal fold here makes a double line of outcrop with a short west outcrop following the line of the pike, but dipping below the other rocks both at the north and south, so that its total length is about a mile and a quarter. One sample was taken near the northern end of this west outcrop, No. 184. The main east belt dips below the Chambersburg near the south end of the Stewart farm, and then emerges to the south again.

The length of the outcrops south of the Standard quarries to nearly opposite Tablers Station, including the short west outcrop, is three and a half miles with an average width of 200 feet. If these outcrops were worked to a depth of 100 feet, there would be available nearly 30,000,000 tons.

WEST QUARRY DIVISION.—At the west edge of Martinsburg, another belt of low silica limestone is quarried by the Standard Lime and Stone Company. It dips at a high angle east beneath the Chambersburg, and the Middle and Lower Stones River Limestones outcrop to the west of the quarry.

The west belt extends north across the Fair Grounds to the railroad near the Standard lime-kilns where it narrows and disappears. Just north of the county road west of the Baltimore and Ohio Railroad and south of the kilns, this belt is 50 to 60 feet wide, and is of high degree of purity. Samples B-11 and B-12 were taken south of this county road and about 350 feet apart, north and south. B-13 and B-14 were taken just north of this road, while B-15 and B-16 were taken 800 and 1050 feet north of the road. The analyses were made by an outside company for the purpose of testing the property a few years ago:

	B-11	B-12	B-13	B-14	B-15	B-16
Silica	0.385	1.02	1.18	0.52	1.04	0.52
Lime carbonate	98.60	98.20	98.40	99.20	98.20	99.20
Magnesium carbonate	trace	0.75	0.43	trace	0.30	0.25

A short, narrow belt to the east of the main outcrop on this same farm showed a higher silica, and probably is a fairly pure limestone in the Beekmantown. The samples were taken from blasted holes, 20 feet apart from east to west, with a 40-foot interval between samples A-4 and A-6. The belt has a length of nearly 400 feet:

	A-2	A-3	A-4	A-6
Silica	1.20	1.16	0.66	1.94
Lime carbonate...............	98.20	98.60	93.80	89.80
Magnesium carbonate.........	0.32	trace	4.81	7.52

A little further south at the Standard west quarry, three samples were taken from different portions of the quarry, Nos. 205, 206 and 217. This west belt was followed south across the Tuscarora grade road to the west lane, three-fourths mile south of this road, and to the west of the Cumberland Valley Railroad, where sample No. 207 was taken. This belt is again well exposed in the railroad cut a quarter-mile or less south of the last, and just beyond the vinegar plant, and its composition is shown by analysis No. 208.

This belt crosses the Arden road about half-way between the Winchester Pike and the railroad, but it here appears to be narrow in outcrop. Its composition near this Arden road is shown by analysis No. 209. These analyses were made in the Survey laboratory:

	No. 205	No. 206	No. 217	No. 207	No. 208	No. 209
Silica	1.54	0.32	0.37	0.28	0.54	0.39
Lime carbonate.......	94.97	98.54	98.98	98.95	98.72	98.56
Magnesium carbonate.	2.45	1.45	1.03	1.11	0.58	1.15
Iron and alumina.....	0.37	0.18	0.11	0.15	0.15	0.16
Loss on ignition.....	0.43	.....	.....	.....	.....	.....
	99.76	100.49	100.49	100.49	99.99	100.26

This west belt appears to be faulted out a short distance south of the Arden road and disappears. A small outcrop is found on the road west from Pikeside to the railroad, which may represent a corresponding ledge to this west quarry belt, but this correlation is doubtful. Its composition at this place, a short distance west of the Winchester Pike, is shown by analysis No. 215:

	No. 215	No. 216
Silica	1.41	1.73
Lime carbonate	97.77	94.75
Magnesium carbonate	1.27	3.81
Iron and alumina	0.17	0.25
	100.62	100.54

Another belt, which is regarded in this district as a direct continuation of the West Quarry Belt, has been opened by the Standard Company to the west of its south quarry belt, nearly two miles south of the center of Martinsburg. At this quarry the dip is west, while the south quarries dip east, and the West Quarry belt described above dips east. Further, this new Standard quarry belt can be traced north to the south edge of Martinsburg just east of the Winchester Pike on a new street that leads east from the pike, where sample No. 216 was taken. It can then be traced north to the toll-gate where the Arden road branches off from the pike to the southwest. At this point on the east side of the pike road, the belt has a width of eight feet and pinches out entirely. At this place the West Quarry belt outcrops over 1,000 feet to the west. As this new quarry belt is traced in opposite direction, or south, it curves to the east and joins the south quarry belt on the pitching nose of the anticline. It is the western limb of this anticline.

The length of the West Quarry Belt from the lime-kilns south beyond the Arden road is two and a half miles, and the width varies from 50 to 225 feet. If we assume an average width of 100 feet, and the rock is worked to a depth of 100 feet, there would be available, allowing a million tons removed in the west quarry, 9,000,000 tons of low silica limestone.

DARKESVILLE-BUNKER HILL DIVISION.—The main belt of Upper Stones River Limestone traced from the river south past Martinsburg dips under the Chambersburg Limestone southeast of Tablers Station and east of the Winchester Pike. It emerges again near the county road leading east to the Opequon, a mile northwest of Darkesville, and then continues south into Virginia, where it was observed to the east of Clearbrook.

Just south of this east road from the pike, sample No. 186 was taken. This belt crosses the county road leading east from Darkesville and at a point about a half mile east of that place, where it is 200 to 225 feet wide. This limestone was tested in car-load lots from openings made just south of this road, and the results are given below as, **A**, **B**, **C** and **D**:

	"A"	"B"	"C"	"D"	No. 186
Silica	0.40	0.30	0.46	0.44	0.42
Lime carbonate	95.74	92.13	97.04	97.20	97.75
Magnesium carbonate	2.70	4.95	1.50	1.35	0.99
Iron and alumina	.....	.....	.....	.....	0.25

The outcrop of this belt is exposed on the next two roads south and a mile east of Inwood. Good outcrops are found on Mill Creek and in the town of Bunker Hill. Large quarries are operated a mile and a quarter south of this town on this belt by the J. E. Baker Lime Company. The composition of the limestone at these quarries is shown by the following Survey analyses. **A** and **B** were made in 1905, taken 200 feet apart, while sample **No. 164** was taken in 1915:

	1905		1915	
	"A"	"B"	No. 164	No. 165
Silica	0.60	0.59	0.29	0.23
Lime carbonate	97.17	97.05	98.20	98.83
Magnesium carbonate	1.26	2.63	1.29	0.58
Iron and alumina	0.46	0.47	0.19	0.20
	99.49	100.74	99.97	99.84

This belt was followed further south to beyond the State Line. A sample was taken near the south end of the county just west of Paynes Chapel, or three-fourths mile southeast of Ridgeway, **No. 165**. In the fields here, the stone outcrops in good ledges with a width of 200 feet, and it is well exposed from here south into Virginia.

The length of this portion of the Martinsburg Quarry Belt from north of Darkesville to the County Line is seven miles with an average width of 200 feet; and worked to a depth of 100 feet, deducting one and a half million tons probably removed in the Bunker Hill quarries, would yield probably 56,000,000 tons of low silica limestone.

The above discussion shows the great importance of the so-called Martinsburg Quarry Belt in its different divisions. It is almost a continuous belt from the Potomac River to the Virginia Line; and on it are now located some very large quarries, with abundant space for many more. It is probably the most important and valuable single belt of rock in the State, and it will for many years be able to supply the steel furnaces with a very superior fluxing limestone. The estimates given above on tonnage indicate an approximate total tonnage in this belt yet available of 227,000,000 tons. If this rock was sold at 50 cents a ton, it would yield $113,500,000.

Falling Waters Belts.

Just west of Falling Waters is a belt of low silica limestone which forms a long, narrow outcrop in the form of an anticlinal fold dipping at the north under the Chambersburg Limestone about three-fourths mile north of the road leading west from Falling Waters. It extends about a mile south where the anticline dips under the shales, with a minor syncline on the east side which brings the shales to the surface in a narrow belt extending north nearly to this Falling Waters west road. The belt is, therefore, about a mile and three-fourths long with an average width of 225 feet. If this outcrop was worked to a depth of 100 feet, it would represent about 16,000,000 tons of available low silica limestone. The northern portion of the belt is owned by the Standard Lime and Stone Company, but no quarries are opened in it. This outcrop is well exposed on the west bank of Falling Waters Run, a quarter mile west of the town. The Chambersburg Limestone over it, at the east, dips east 35 degrees; and the same limestone to the west of the belt dips west 20 degrees. The belt is thus on the center of an anticlinal fold, and it has a width at this place of 350 feet, becoming more narrow to the north and south. A sample was taken of this opening about the center, No. 30. This is a light-dove-colored limestone breaking with the smooth, shelly fracture, and shows some indistinct bird's-eye effect from calcite spots. Sample No. 31 was taken from the west wall of the outcrop, and the rock has a similar appearance to the other sample.

To the south on the next cross-road about 700 feet west of the Williamsport Pike, this belt of low silica limestone outcrops at the bend of the road in the woods along a step ravine on the Porterfield farm. It there has a width of 225 feet. On the eastern side of the outcrop, it dips 30 degrees east, and there is a western dip on the western side of the belt. This outcrop was sampled on the western side, No. 35. It was sampled near the center, No. 36. The belt disappears a short distance south of this road:

	No. 30	No. 31	No. 35	No. 36
Silica	0.65	0.65	0.87	0.84
Lime carbonate	98.73	98.60	98.67	98.85
Magnesium carbonate	0.93	1.11	0.28	0.30
Iron and alumina	0.16	0.15	0.20	0.16
	100.47	100.51	100.02	100.15

East of Falling Waters.—About one mile southeast of Falling Waters, there is an outcrop of low silica limestone in a ravine or draw just south of the Potomac River, which is controlled by a syndicate of local people, and it is known as the Syndicate belt. The erosion in this valley has removed the overlying Chambersburg and has exposed a good width of the low silica limestone of the Upper Stones River which dips to the north and south under the higher silica rock.

The belt is exposed north and south with a length of about 1,800 feet and a width of 315 feet. The rock dips east 35 to 40 degrees. The stone is a light-gray or dove-color, breaking with the smooth, shelly fracture, and is low in silica. At the north, the river bluffs are all Chambersburg Limestone with about four per cent. silica, but the low silica limestone is said to outcrop at the base of the vertical cliff at the water-level. This point could not be reached from above. There would be in this outcrop worked to a depth of 100 feet approximately 4,300,000 tons of limestone. Samples were taken across this outcrop. No. 37 was from the east wall. No. 38 was taken from the center. No. 39 is from near the west wall, while No. 41 is from near the north end of the ravine outcrop:

	No. 37	No. 38	No. 39	No. 41
Silica	0.41	0.33	0.32	0.38
Lime carbonate	98.47	98.73	98.76	98.70
Magnesium carbonate	1.11	0.90	0.92	0.96
Iron and alumina	0.24	0.20	0.23	0.18
	100.23	100.16	100.23	100.22

National Limestone Belt.

Two miles southeast of Martinsburg and east of the Standard quarries, an anticlinal fold in the Martinsburg Shales brings the Chambersburg and Stones River Limestones to the surface in an elongated, lenticular outcrop. On this outcrop the National Limestone Company quarries are located.

On the eastern side of the fold, the Upper Stones River low silica limestone is exposed in a continuous belt with an east dip of 40 to 50 degrees. On the western side, the low silica limestone shows at the north and again toward the south, but the outcrop is not continuous. The dip is about 40 degrees west. Between the two belts along the center of the fold, the underlying Beekmantown Limestone is exposed. The cauliflower chert horizon of this limestone is close to the east outcrop belt of Stones River, so that the Lower and Middle Divisions of the Stones River are very thin or absent.

The fold dips or pitches to the north, so that the Chambersburg Limestone passes under the shales to the south of the Baltimore and Ohio Railroad; and the Stones River dips under the Chambersburg almost a half mile south of the Charlestown county road which leads past the Sutton Schoolhouse to the Opequon. Traced southward, the Chambersburg dips under the shales near the east lane that follows Buzzard Run east from the Winchester Pike. The Stones River outcrop ends a little over a half mile north of this place, or just south of the lane that leads east toward Sulphur Spring Run.

The length of this east outcrop of low silica stone is two and three-fourths miles with an average width of 225 to 250 feet.

The west belt extends south nearly to Evans Run, with a small, narrow outlier just south of this run. It again outcrops with short length to the north and south of the road which leads east from the Winchester Pike at Pikeside. The total length of exposed western outcrop is one and a fifth miles, with a width at the north of 140 to 160 feet, and only 40 to 50 feet near Evans Run. This narrow portion of the belt shows an exceptionally pure limestone containing over 99 per cent. lime carbonate in analyses of car-load lots. Where the east and west belts come together on the north-dipping end of the fold, the width over a length of 400 feet is 1,000 feet. The available tonnage of low silica in the two outcrops on this fold, according to the above measurements and worked to a depth of 100 feet, would be 33,000,000.

Nearly all this outcrop is owned by the National Limestone Company, and their quarries and plant are described in the preceding Chapter. A number of chemical analyses have been made on this belt at different times. The following analyses were made in 1905 from samples taken from blasted holes, three to six feet deep. Numbers 1 to 8 were taken across the 1,000 feet of outcrop at the north end of the fold, while the others were taken from north to south on the west outcrop to Evans Run:

No.	Lime Carbonate	Magnesium Carbonate	No.	Lime Carbonate	Magnesium Carbonate
1	98.00	0.50	16	98.80	1.10
2	97.60	0.48	17	98.00	0.40
3	94.00	1.50	18	97.10	1.60
4	96.50	0.70	19	98.50	0.45
5	97.50	0.60	20	98.60	0.50
6	96.00	0.82	21	97.80	1.40
7	97.00	0.50	22	97.50	1.20
8	98.60	0.80	23	97.40	0.90
9	98.00	0.65	24	97.50	2.40
10	98.50	0.30	25	96.40	1.90
11	95.60	1.70	26	97.00	0.70
12	95.70	2.30	27	98.60	0.24
13	97.80	1.90	28	97.80	0.32
14	97.40	0.70	29	97.00	2.00
15	98.80	1.10	30	98.00	0.88
			31	98.80	0.40

The above analyses on this west outcrop show a very low silica limestone with some outcrops of high silica stone which can readily be separated. The average composition of this belt, according to these analyses, would be 97.48 per cent. lime carbonate and 1.00 per cent. silica. The east outcrop is much lower in silica and averages around a half of one per cent.

The following analyses were made of this east outcrop in the Survey laboratory. A new quarry has been opened near the north end of the east outcrop and now has a depth of 18 feet. Sample No. 93 was taken near the bottom of this new quarry, and it is a dark-gray rock. No. 94 was taken about fifteen feet higher in the formation, but at about the same level in the quarry. No. 95 is an average of 15 feet vertical in the quarry, while No. 96 was taken from a hole below the present quarry floor. No. 97 is from a ledge of higher silica stone, about 75 feet west of the deep No. 1 quarry, and it may represent a thin remnant of the Middle Stones River. No. 98 is the medium-grade stone on the west wall of this deep quarry. No. 182 is further south on this east belt and near the south end of the No. 2 quarry and south of Evans Run:

	No. 93	No. 94	No. 95	No. 96	No. 97	No. 98	No. 182
Silica	1.49	1.16	0.93	1.53	3.21	1.36	0.60
Lime carbonate	96.07	97.04	97.46	96.30	83.36	95.88	97.49
Magnesium carbonate	2.57	1.94	1.49	2.11	12.74	2.63	1.42
Iron and alumina	0.32	0.20	0.22	0.35	0.53	0.37	0.47
	100.45	100.34	100.10	100.29	99.84	100.24	99.98

The National Limestone Company, prior to the purchase and development of this tract, made diamond core drillings over the property under the supervision of the writer, and the analyses of these cores were made by A. S. McCreath and Son, at Harrisburg, Pa. A few of these records are given to show the character of the Stones River Limestone with depth. **Hole No. 1** was drilled near the north end of the east outcrop and the analysis shows a very pure limestone to the bottom of the hole, 62 feet. **Hole No. 4** was drilled north of the good limestone outcrop on the overlying Chambersburg, but struck the Stones River at a depth of 85 feet, showing that this limestone continues northward below the surface. **Hole No. 7** was drilled near the south end of the west outcrop in the very high-grade limestone of that area. **Hole No. 8** was drilled a short distance east of No. 7. **Hole No. 19** was drilled near the south end of the property and about three-fourths mile north of the extreme south end of the outcrop of Stones River:

	Hole No. 1	Hole No. 4		Hole No. 7	Hole No. 8	Hole No. 19
	0-62 ft.	0-85 ft.	85-130 ft.	0-21 ft.	0-130 ft.	0-125 ft.
Silica	0.27	11.72	0.32	0.28	0.78	0.36
Lime carbonate	98.53	78.48	98.30	98.86	97.08	98.41
Magnesium carbonate	0.74	5.36	0.86	0.67	1.50	1.10
Iron and alumina	0.42	4.29	0.43	0.25	0.57	0.20
	99.96	99.85	99.91	100.06	99.93	100.07

Blair Limestone Belt.

East of Opequon Creek and north of the main line of the Baltimore and Ohio Railroad, an anticlinal fold brings the Chambersburg, Stones River, and Beekmantown Limestones to the surface in the Martinsburg Shale area. The Chambersburg Limestone extends south of the railroad for nearly two miles before it dips under the shales, but the Stones River Limestone plunges beneath the Chambersburg north of the railroad. The cuts of the railroad at this place show outcrops only of Chambersburg which are thrown into minor folds.

Traced to the north, the Chambersburg Limestone dips under the shales near the east bend of Opequon Creek toward the river, and the Stones River dips under the Chambersburg a mile further south. The length of the anticlinal outcrop of Chambersburg is over seven miles with a width near the center of the fold of three-fourths mile. Along the center of the fold is a lenticular outcrop of Beekmantown Limestone.

The Upper Stones River low silica limestones outcrop on the eastern and western sides of this fold, and they are locally known as the east and west belts. The west belt has an average width of 300 feet; and the eastern belt, 200 to 250 feet. On the dipping ends of the fold at the north and south, the two belts unite into one outcrop.

At the south end, the two belts unite just south of the

Blair quarries and then dip in a short distance under the Chambersburg. At the north, the two belts come together near the road which crosses the Opequon at Myers Bridge, and then continue north for a half mile as a single outcrop, though even here there is a very narrow belt of siliceous limestone between the two outcrops of low silica stone. At this place the western portion of the belt has a width of 350 feet and the eastern portion is about 175 feet, or a total width of 525 feet near the county road.

In the Blair quarry north of the Schoppert Ford road which is three-fourths mile north of the railroad, a minor syncline brings the Chambersburg into the quarry, dividing the east belt for a short distance into two divisions. These outcrops of Stones River Limestone are marked by minor folding which complicates the structure. The two separate belts have a total length of three and a fourth miles and an average total width of 500 feet. At the north, the united belts have a length of three-fourths mile with an average width of 400 feet. In all the outcrops on this anticlinal fold, by the above measurements, worked to a depth of 100 feet, there would be available 90,000,000 tons of low silica limestone.

The south end of this outcrop with a length of nearly a mile and a half is controlled by the Blair Limestone Company which has opened large quarries and operates a crushing plant and lime-kilns as described in the preceding Chapter. This is the only operating plant on the belt. The Carnegie Steel Company owns a small tract just south of the Blair near the railroad. North of the Blair property is a tract owned by the LaBelle Iron and Steel Company, of Steubenville and Wheeling. To the west of the LaBelle property is a tract owned by the Standard Lime and Stone Company, while the lands to the north are owned by a Martinsburg syndicate.

The northern portion of this outcrop is one and a quarter miles from the Cumberland Valley Railroad at Berkeley Station, and at this point could be connected with the Baltimore and Ohio connecting switch. The proposed cut-off of this latter railroad via Shepherdstown to Harpers Ferry would pass across the outcrop at the north end of the LaBelle property.

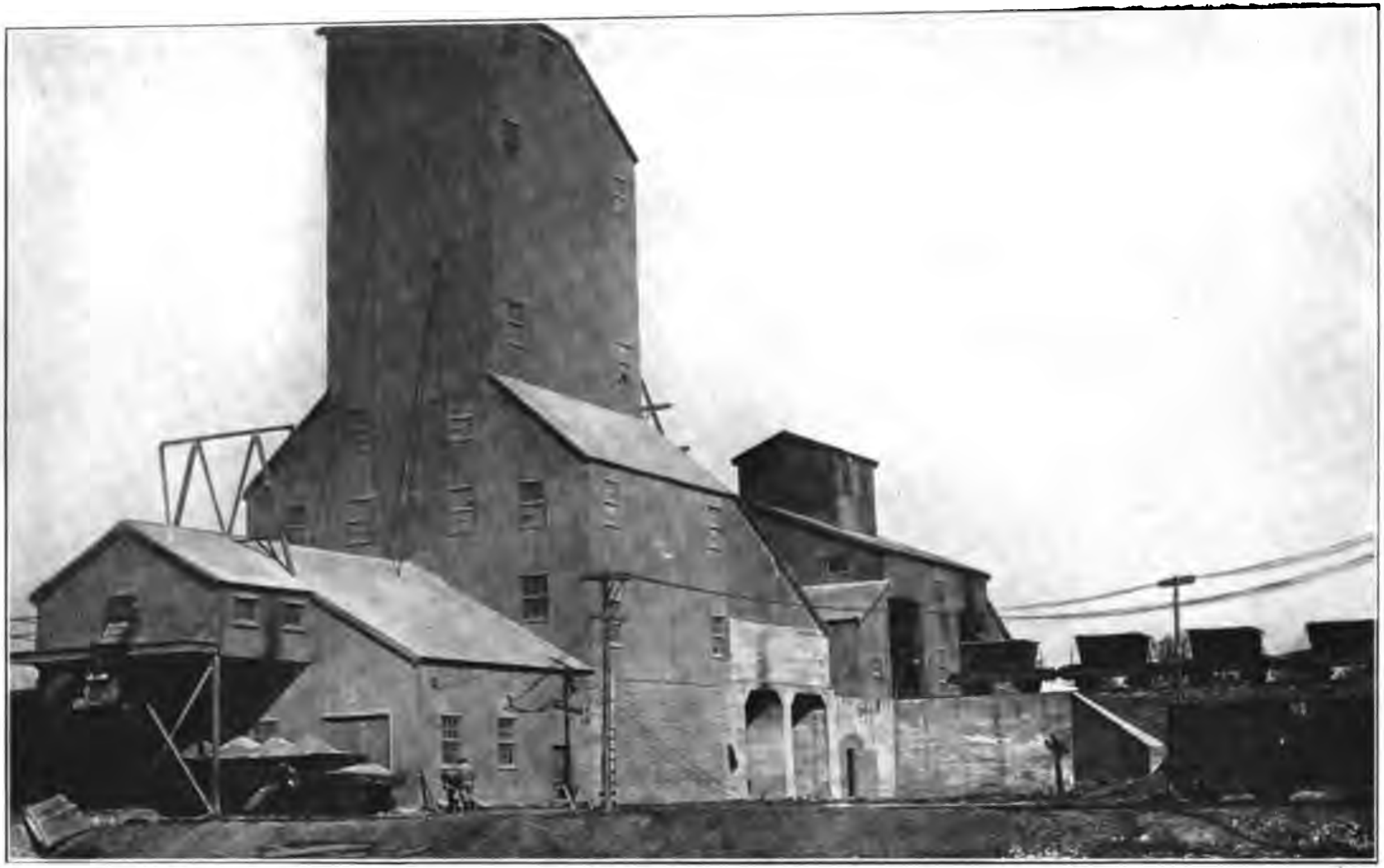

PLATE XXX.—National Limestone Quarry in Upper Stones River Limestone.

This outcrop is 40 to 80 feet above the creek level, so quarries could readily be drained, and the rock is low in silica over most of the outcrops.

The chemical composition of the limestone at the Blair quarries is shown by the following analyses. A-1 and A-2 are from the furthest south quarry on the east belt. B-1 and B-2 are from the present working quarry further north on this east belt. C-1 to C-3 are from different parts of the new quarry north of the Schoppert county road, or about a mile north of the first quarry (A):

	A-1	A-2	B-1	B-2	C-1	C-2	C-3
Silica	0.76	0.88	0.76	0.40	0.72	0.40	0.48
Lime carbonate......	97.41	97.02	97.00	98.65	97.54	98.30	97.77
Magnesium carbonate	1.32	1.80	2.46	0.30	1.50	1.21	1.51
Iron and alumina....	0.72	0.30	0.48	0.30	0.72	0.46	0.42

The following analyses were made by one of the steel companies about seven years ago, across the west belt of the present Blair property, over a width of 400 feet. Each analysis represents an average of 40 feet in width of outcrop, and they are arranged in the table from west (No. 1) to east:

	No. 1	No. 4	No. 6	No. 8	No. 10
Silica	0.67	0.49	0.39	0.92	0.76
Lime carbonate......	88.79	91.71	94.94	88.95	91.18
Magnesium carbonate.	9.95	7.05	4.16	9.38	7.25
Iron and alumina.....	0.28	0.28	0.26	0.20	0.32
	No. 12	**No. 14**	**No. 16**	**No. 18**	**No. 20**
Silica	0.60	0.50	0.35	0.32	0.35
Lime carbonate.......	94.84	96.80	97.97	97.52	97.68
Magnesium carbonate.	4.16	2.30	1.44	1.78	1.51
Iron and alumina... .	0.23	0.38	0.23	0.28	0.23

The silica is low in all these samples, and the magnesia decreases eastward on the belt with a corresponding increase in lime carbonate.

In 1905, the writer secured samples of the limestone on the present Blair tract, which were analyzed in the Survey laboratory, and these are given below by numbers. The lettered analyses were made about that time by one of the steel companies. About a quarter mile north of the north Blair quarry (C, above table), is a fish-pond, near which are good exposures of the limestone. To the west of this pond is the outcrop of the west belt where samples "A" and No. 149 were taken. East of this belt is a higher silica limestone, increasing in amount of silica as traced eastward, illustrated by analyses "B", "C", and No. 160; then comes a dolomite still higher in silica, No. 167 and No. 168. Further east is the outcrop of the east belt, here 400 feet wide. No. 150 was taken near the west side of this east belt, and "D" near the east side of the belt. No. 148 is the Chambersburg Limestone just east of the east belt:

	"A"	No. 149	"B"	"C"	No. 160
Silica	0.25	0.58	1.58	1.80	3.83
Lime carbonate.......	99.07	98.98	93.85	92.03	92.08
Magnesium carbonate	0.31	0.43	3.33	5.24	3.48
Iron and alumina.....	0.37	0.75	1.24	0.93	1.14

	No. 167	No. 168	No. 150	"D"	No. 148
Silica	4.43	3.85	0.79	0.74	5.77
Lime carbonate.......	59.36	58.47	99.36	98.42	90.73
Magnesium carbonate.	36.08	37.50	0.23	0.57	2.33
Iron and alumina.....	0.91	0.92	0.31	0.27	1.85

Further north on the lane that leads west to Opequon toward the Eagle Schoolhouse, a sample was taken from the west belt outcrop not far from the creek, No. 201. From the east belt near the north-and-south county road, No. 202 was taken. About a mile further north on the east-and-west county road that leads west to the Opequon at Julep Bend, a sample was taken from the east belt, No. 203. Sample "A" is from the west outcrop belt and about a half mile north of this road:

	"A"	No. 201	No. 202	No. 203
Silica	0.50	1.05	1.01	1.09
Lime carbonate...............	96.45	96.96	96.70	97.01
Magnesium carbonate.........	1.51	1.23	1.99	0.92
Iron and alumina.............	1.60	0.25	0.40	0.37
	100.06	99.63	100.10	99.39

The limestone between the east and west belts appears to be the Beekmantown, and near the west belt it is a dolomite high in silica. The following analyses were made of this dolomite a half mile north of the county road mentioned in the preceding paragraph, and just east of the west outcrop belt.

"A" and "B" are dark-gray, almost black rocks, while "C" is a light-gray. "D" is the Chambersburg Limestone just west of the Stones River west belt, in this same location. "E" is the Chambersburg a half mile north of sample "D":

	"A"	"B"	"C"	"D"	"E"
Silica	6.16	4.50	7.60	6.70	3.50
Lime carbonate.......	73.17	60.19	55.77	89.79	87.48
Magnesium carbonate.	18.78	33.92	34.82	2.27	8.18
Iron and alumina.....	1.80	1.60	2.00	1.20	1.00

On the county road further north which leads east to Greenburg and west to the Opequon, the two belts are still separated by about 600 to 750 feet of Beekmantown Limestone. Sample "F" was taken from 70 feet of outcrop near the west side of the west belt. The total width here was 400 feet. Sample "I" was taken near the west wall of the east belt and its amount of silica would indicate that it was probably off from the belt:

	"F"	"G"	"H"	"I"
Silica	1.64	0.69	1.50	2.20
Lime carbonate...............	93.84	96.82	94.15	95.17
Magnesium carbonate.	3.18	1.29	1.83	1.51
Iron and alumina............	1.40	0.62	2.40	1.30

The following analyses were made by one of the steel companies on samples taken from a trench excavated east and west near this Greenburg road. The samples were taken across a width of 50 feet each, and the ones quoted are from the central portion of the west belt over a width of 400 feet:

Silica	1.09	0.76	0.82	1.00	0.55
Lime carbonate.......	95.60	95.90	95.81	95.67	96.67
Magnesium carbonate.	3.19	1.82	1.83	1.74	1.59
Iron and alumina.....	0.80	1.10	1.45	1.30	1.05

The following analyses were made by this same company near this same road across the east belt for a length of 250 feet. The samples were taken over each 50 feet from west to east. The silica runs high in this belt, according to these analyses, as is also indicated by the Survey analysis "I" given in the second table above:

Silica	1.66	1.34	1.42	1.01	0.23
Lime carbonate	90.73	92.27	95.99	95.56	97.41
Magnesium carbonate	5.51	2.72	0.75	1.69	1.39
Iron and alumina	2.02	3.41	2.06	1.48	0.66

Further north on the road east of Opequon Creek at Myers Bridge, the two belts are practically one, separated by a very narrow belt of higher silica stone. The width is about 400 feet with a dip increasing eastward from 30 to 52 degrees east. The limestone is a light-gray to dove-color, and breaks with smooth, shelly fracture. The ledges are well exposed, and the Chambersburg Limestone outcrops on the east and west sides of the Stones River low silica rock.

Analyses were made of this limestone from samples taken just north of the county road. No. 16 was taken near the west wall of the belt. No. 17 was taken about the center of the belt. No. 18 represents the higher silica limestone separating the east from the west outcrop. In the work of quarrying this outcrop, the higher silica rock of No. 18 could be left as a wall between the two belts, or it could be removed and used as ballast:

	No. 16	No. 17	No. 18
Silica	1.00	0.91	2.36
Lime carbonate	98.06	97.68	92.76
Magnesium carbonate	1.13	1.52	4.96
Iron and alumina	0.37	0.23	0.26
	100.56	100.34	100.34

Opequon Limestone Belt.

A belt of Stones River Limestone outcrops just east of Opequon Creek in the extreme southwestern corner of Jefferson County, three miles east of Ridgeway Station on the Cumberland Valley Railroad, and four miles west of the Baltimore and Ohio Railroad at Summit Point. This outcrop was found in Virginia just north of Wadesville with an east dip of 35 degrees. It probably crosses the Baltimore and Ohio Railroad near Wadesville, which is a mile and a half south of the State Line, so that this outcrop can readily be reached from the railroad.

The outcrops of Chambersburg and Stones River Limestones are here in an anticlinal fold, with the Chambersburg on the west side dipping 35 degrees west; and on the eastern side of the fold, the dip of the Chambersburg is 15 to 20 degrees east. This fold brings these limestones to the surface through the shales. The Martinsburg Shale is faulted out on the east side of the fold near the north end, so that along most of this eastern side the Beekmantown Limestone is faulted against the Chambersburg.

The fold dips to the north and the limestones pass under the shales south of Turkey Run. The fold continues south to Wadesville, Virginia, but it was not followed south of this place in the present work. The length of the limestone outcrop in Jefferson County is three miles with a maximum width of three-fifths mile. The Stones River outcrops near the eastern side of the fold. The Upper Division appears to be absent, but the Middle Division is well shown carrying a large quantity of black flints. The soil near the road leading north is thickly strewn with these flints, a half to one inch in size. The flint horizon continues north along this road for over a mile. Associated with these flints are ledges of light-gray, high-grade limestone, which has the appearance of being low in silica. This horizon is the Middle Stones River.

The Middle and Lower Stones River are well exposed on the next road north which leads west to the Opequon near the mouth of Silver Spring Run, and the Upper horizon still contains ledges of the good limestone. The Lower division is composed of dark-blue to bluish-gray dolomites, apparently high in silica.

The Stones River Limestones dip under the Chambersburg south of the east-and-west lane south of Turkey Run. Whether this belt of Middle Stones River contains a sufficient tonnage of low silica limestone to justify development can not now be told. It would require trenching and excavation with a large number of analyses to settle this question, but the Middle Division of this formation seldom contains any large quantity of low silica limestone. One sample was taken of this limestone on the east-and-west county road that leads from the Opequon to Summit Point, and at a point just east of the first road to the northeast of the creek, No. 166 (given in next table of the Leetown belt).

Leetown-Van Clevesville Limestone Belt.

The broad belt of Martinsburg Shale through which the Opequon Creek Valley is cut is bounded on the east by a belt of Chambersburg Limestone from near the mouth of the Opequon, south across Berkeley County and across Jefferson to beyond Middleway. On the eastern side of this Chambersburg Limestone belt there is an outcrop of Stones River Limestone which can be traced over most of the distance.

This belt of Stones River is exposed not far above the mouth of the Opequon and can be traced without a break to a point over a mile south of Van Clevesville, where, near the Van Metre Schoolhouse, the outcrop disappears. It is seen again further south near the east edge of Leetown, and then can be followed south to about three-fourths mile north of Middleway. No trace of it is seen further south on this belt.

At the north, its width is 100 to 150 feet, and it is a light-gray to cream-colored limestone, breaking with smooth fracture, and closely resembles the rock in the Martinsburg quarries. No quarries are opened on this belt and no tests have been made on the stone. The outcrops remote from the railroad are too narrow to justify the building of connecting switches. The favorable location and one that should be examined is near Van Clevesville where the limestone belt crosses the railroad and passes under the town. The outcrops in this area are for some distance near the railroad. No fossils were found in this belt of limestone, and the correlation of this limestone with the Upper Stones River is therefore doubtful; but its relation to the overlying Chambersburg, its low silica, and its general appearance, would indicate that it belonged in this division.

A sample of this limestone was taken on the second short west road, a mile and three-fourths south of Greenburg, No. 204, where the width is 100 feet, though the outcrop is partly concealed by soil. No. 190 was taken on the next county road, three-fourths mile south of the last sample. This location is about a mile and a quarter east of the Opequon, and the belt appears to be still about 100 feet wide. The outcrop was then followed south across the fields, and sample No. 191 was taken a mile further south and back of the house just north of the railroad:

	No. 166	No. 204	No. 190	No. 191
Silica	0.64	1.76	1.97	1.80
Lime carbonate	97.23	95.68	94.71	93.90
Magnesium carbonate	1.94	1.87	2.55	3.35
Iron and alumina	0.25	0.42	0.46	0.35
	100.06	99.73	99.69	99.40

This belt is 100 to 150 feet wide east of Leetown. The outcrop is clearly exposed on the road to the east of the Smithfield Pike about one and three-fourths miles northeast of Middleway, where it is seen on the little south crook of this road. It is not exposed on the road east from Middleway to Charlestown.

Two short belts of Stones River outcrop on the eastern sides of the folds to the west of Middleway, and at the east edge of the town. Each has a length of about a mile and a half with a width of 100 feet; but no tests were made on these outcrops, though they appear to be low in silica. They are too far removed from railroads for present development.

The total length of the Stones River outcrops from the mouth of the Opequon to beyond Leetown is nine miles. The two short belts west of Middleway would total three miles, or a total length of outcrops of 12 miles. If the average width be taken as 100 feet and the stone worked to a depth of 75 feet, there would be available 38,000,000 tons of this limestone.

Whitings Neck Limestone Belt.

The Whitings Neck bend of the Potomac River is east of the mouth of the Opequon, and the area is mostly covered by Beekmantown Limestone. Three-fourths mile east of Opequon Creek and to the east of the north-and-south county road, is a broad belt of fairly high-grade limestone, higher in silica than the quarry rock at Martinsburg, which represents the pure limestone belts in the Beekmantown Formation. This group of rocks was described in the early part of the present Chapter.

Further east, near where the east part of the county road along the river turns north and near the western part of the Neck, there is an outcrop of Stones River Limestone which extends north to the river. It extends south, just west of the house on the east lane from the north-and-south road, and it forms steep bluffs on the river bend further south on the next farm. The outcrop is found again on the east-and-west road leading from Foltz to Scrabble, just east of the road that leads north to Whitings Neck. It also is found a short distance east of Swan Pond and disappears a short distance south.

On the road from Foltz east to Scrabble, the Beekmantown Limestone to the west of the Stones River outcrop dips 60 degrees east; and east of this outcrop, the Beekmantown dips 40 degrees west. The structure is thus a syncline bringing to the surface the Stones River, but no trace of the Chambersburg. The width of the outcrop of high-grade stone is 250 to 300 feet.

This limestone was sampled on the short lane east to the house at the south end of Whitings Neck, No. 220. A sample was taken east of the next house to the south, No. 218, and was near the west side of the outcrop. The house stands on a good outcrop of the pure limestone of the Beekmantown which extends north to the river bluffs. The two outcrops of Beekmantown and Stones River are here very close together and have a very similar appearance, but balls of chert of good size are associated with the former limestone, and the surface of the ground is dotted with them:

	No. 220	No. 218
Silica	3.42	1.73
Lime carbonate	92.83	94.75
Magnesium carbonate	2.69	3.81
Iron and alumina	1.15	0.25
	100.09	100.54

The length of this outcrop of Stones River Limestone is five miles. If an average width of 250 feet be assumed for the belt, and worked to a depth of 100 feet, there would be available about 50,000,000 tons of limestone. This belt was tested at the north, but most of it has not been closely investigated, so that the above estimate is based on very meager data and can only be regarded as suggestive as to the real value of this belt. Over the greater portion of Jefferson County, there is no trace of this Stones River Formation and the limestone outcrops all belong to the lower formations which are higher in silica and magnesia. While such limestones have little or no value as fluxing stone, they are valuable for other purposes as outlined in the preceding Chapter.

RESUME.

The review of the low silica fluxing limestones given in this Chapter shows that very pure, high-grade limestones are found at a number of places in the Beekmantown Formation in Berkeley and Jefferson Counties, but that they are usually too high in silica to compete with the Upper Stones River belts.

The Upper Stones River Limestones are exceptionally low in silica, and nowhere else in this country can so extensive deposits of this grade of rock be found. Large quarries are in operation upon these belts owned by six companies. Tracts are owned and held for future development by steel companies, while other tracts are owned by quarry companies and held in reserve, and still other tracts are owned by local syndicates for investment.

Inquiries for tracts of this grade of stone are frequent, and from time to time detailed tests and examinations are made by outside companies with the object of securing suitable locations for quarries. These limestone lands are held at prices ranging from $160 to $300 per acre, depending on the location.

These belts represent a large value and are important assets of the county. Estimates of tonnage have been made in this Chapter, based in some cases on somewhat meager data. The working depth of 100 feet is based on drill and quarry records, but it would require much more drilling to prove the depth on the untested lands. The estimates while, therefore, approximate are of interest and are suggestive as to quantity of this valuable limestone yet available in the ground. With the present great development of the steel industry, the limestone industry should have a future growth far greater than in the past. The attention of the iron and steel trade will be directed more and more to this field with its advantages of low silica in the rock, low freight rates, and low quarry cost.

In the following table, these tonnage estimates are brought together to illustrate the value and possibilities of this field, giving the tonnage available from open quarrying. It could probably be doubled or even trebled by underground mining in the remote future:

Estimated Tonnage of Low Silica Limestone in Berkeley and Jefferson Counties.

	Tons
Martinsburg Quarry Belt	227,000,000
Falling Waters Belt	20,000,000
National Limestone Belt	33,000,000
Blair Limestone Belt	90,000,000
Opequon Belt (not estimated)	....
Leetown-Van Clevesville Belt	38,000,000
Whitings Neck Belt	50,000,000
Total	458,000,000

CHAPTER XVI.

THE LIME AND CEMENT RESOURCES OF THE EASTERN PANHANDLE COUNTIES.

LIME AND LIME HYDRATE.

Lime Oxide and Classification of Limes.

Lime oxide or quicklime is usually obtained by burning rocks composed mainly of carbonate of lime, as shells, marl, chalk, or limestone. The process is a simple chemical operation, consisting of driving off the carbonic acid gas by heat, thereby leaving the quicklime or oxide. The amount of lime formed from a given quantity of limestone depends on the purity of the rock from which it is made. One hundred pounds of pure carbonate rock would yield 56 pounds of lime and 44 pounds of carbonic dioxide gas driven off into the air. In the Toledo district, they estimate it requires two tons of limestone to make one ton of lime. Limestones in nature are usually impure, containing magnesia, silica, alumina or clay, iron, sulphur, and organic matter.

Magnesia when present in any considerable amount makes the rock burn at somewhat lower temperature, and also makes it slower in setting time, and it then generates very little heat on hydration so that magnesian limes are called cool limes. The explanation of this lower temperature is given by Emley[1] as due to the chemical fact that magnesium oxide will only combine readily with water when it has been burned at some temperature below 1100° C., which is below the temperature in the ordinary kiln. The hydration of calcium oxide gene-

[1]Bureau of Standards, Bull, 16, p. 15; 1913.

rates heat, but as a large part of the magnesium oxide, on account of high temperature at which it was burned, will not hydrate, it acts as an inert substance which must be heated by the calcium oxide and the hydration does not generate a high temperature. The setting of a plaster is in reality a process of crystallization and the magnesium oxide or hydrate appears to delay this process, so that the plaster sets more slowly.

Silica when present in small amount is inert. If in larger quantity it unites with the lime, forming a slag over the surface of the limestone blocks and prevents their complete calcination and results in underburned blocks. It also lowers the quantity of sand the lime can carry when made into mortar and thus lowers its value to the mason.

Alumina is usually inert, but if present in considerable quantity may with the silica give the lime hydraulic properties. Iron may darken the plaster if present in any quantity and thus interfere with the sale of the product, though it appears to add strength to the plaster.

CLASSIFICATION.—Limes may be classified into four groups in which the differences are due to their impurities. The first two groups are sometimes united under the terms, Pure limes, or Calcareous limes, or High Calcium limes.

Fat or Rich Limes contain less than 10 per cent. of impurities. They usually are quick setting, and in slaking generate usually a high degree of heat and are therefore called **hot limes.** On slaking they expand two to three times their original bulk. This grade will carry more sand than the poorer grades, so it is also called a strong lime.

Lean or Poor Limes contain more than 10 per cent. of impurities, consisting of silica, alumina, iron, etc. They are not made except in sections where richer limes can not be obtained, or where they can find a sale for land fertilizer.

Magnesian or Dolomitic Limes are made from limestones containing 10 to 15 per cent. or more of magnesium carbonate. In slaking they produce a very slight rise in temperature. The expansion is less than in fat limes and they are slow setting. They are also **cool limes.**

A mason using magnesian limes can place two to three times as many brick in a single spread of mortar as he could by using a quick-setting lime. The plasterer can usually make a smoother wall with the slow-setting lime, and where both kinds of lime have been used, the preference is for magnesian limes. In the Mississippi Valley, the demand is for pure lime. This is also true to a large extent in West Virginia, Baltimore, and Washington. In Philadelphia, New York, to some extent in Pittsburgh, and over Ohio, the demand is for magnesian limes.

Hydraulic Limes are made from limestones containing 15 to 20 per cent. of silica and alumina. They may contain magnesia, but if so this element appears to be inert. Such limes slake on burning and mortars made from them will set under water.

Hydraulic Cements are made from similar limestones to the last, but with a higher percentage of silica and alumina. On burning they form a clinker which must be ground to a flour before it can be used.

Setting and Hardening of Lime Mortar.

When water is added to lime it forms a lime hydrate and on exposure to the air, the surplus water is evaporated. The setting of lime mortar is considered to be due to the removal of the surplus water added to it, and the complete formation of the hydrous silicate. The removal of all the moisture by evaporation and the combination of water and silica with the lime oxide would bring the particles into close contact, forming a weak bond by cohesion and probably crystallization, constituting the **set of the plaster.** The time required will vary with the kind of lime, amount of impurities, amount of water and sand used, and the air temperature. In some plasters the reaction would be complete in very short time, and in magnesian limes it may take place after several minutes, or even hours before completed. In some very lean or poor limes it is never completed and the lime does not set. After the set is well started any movement of the plaster will weaken the bond and injure the work.

The hardening of lime plaster is due to the absorption of carbonic dioxide from the air by the plaster, the lime compound forming a carbonate, and the plaster thus tends to pass back of its original chemical composition. This change begins on exposure to the air but requires a considerable length of time before it can be measured. The action continues for years and probably is not completed in a long period of time. Old mortars have been analyzed and show high percentages of lime carbonate. The strength of lime mortar is determined by the process of hardening and so increases with time.

Manufacture of Lime.

When limestone, marl, chalk, or shells, composed essentially of carbonate of lime are heated in a current of air at a temperature of 1562° to 1800° F., the carbonic dioxide is driven off, leaving a lime oxide known as quicklime. In order to generate this temperature there would be required on theoretical calculation 200 to 230 pounds of good coal to burn a ton of lime from a fairly pure limestone as found in the Martinsburg district, but in the kilns now in use in this section it requires 500 to 600 pounds of coal to the ton of lime or about two and a half times the theoretical amount required. There is thus a great waste of heat in burning lime in the ordinary type of kilns. The above figures would in the West Virginia kilns represent about 312 to 375 pounds of coal to the ton of **limestone.** In the Kelley Island district in Ohio on a month's run, it required 315 pounds of coal to the ton of limestone, which figures about 3½ pounds of lime to a pound of coal. The figures on the Martinsburg district on a purer limestone would give 3.6 pounds of lime to the pound of coal, so that the waste of fuel is no greater but a trifle less than in the great lime center at Toledo. In some plants and in some kilns, the figures will be found to show much greater loss in fuel.

Various types of kilns, fireplaces, and burners have been patented which claim to reduce this waste and thus add to the economy of lime manufacture. The cost of fuel represents one-fifth of the total cost of the lime in average plants.

Wood has been the favorite fuel for burning lime from the beginning of the industry. With the growing scarcity of wood and the greater advantages of coal fuel, if it could be adapted to the work of lime burning, various methods were patented and used to render coal an efficient lime fuel. The basic principle of most of these methods is a reinforced or mechanical draught, of which there are two methods and four prominent types.

The two methods of securing increased draught in a kiln are the **forced** and **induced** draught. In the former, the draught is increased by forcing the current of air or steam or both through the fire-boxes from below the grate-bars. In the induced draught, suction is applied at or near the top of the kiln, drawing off the gases and drawing the flame up into the kiln. There is some difference of opinion as to which is the better method and both are used.

The four prominent types of draught now in use are—air, steam, air and a gaseous diluent known as the Eldred process, use of a suction fan at the top of the kiln. The first two represent a forced draught, the last a simple induced draught, while the Eldred process is a combination of the induced and forced draught.

Actual trials have shown that one ton of coal will burn from three to five tons of lime, the variation being in a large part due to method of draught used, and also to method of firing the kiln. There is no question of fuel economy by the use of these added draught appliances, though it is claimed by some lime burners that there is an important question of quality of lime involved.

One cord of wood will burn two to three tons of lime In an ordinary lime-kiln without any artificial draught appliances, one ton of coal will burn about the same amount of lime as one cord of wood, though the heating value of the coal is much greater. The ordinary conditions of a lime-kiln furnace are much more favorable for securing greater efficiency from wood fuel than from coal. Economy of manufacture of lime with coal fuel now demands some form of reinforced draught and lime manufacturers are now recognizing this fact. While it is true that good lime can be made with coal fuel with reinforced draught, it is also true that the careless use of such draught will injure the quality of the lime and too strong draught will also increase the fuel cost beyond the necessary amount.

There are two dangers to the quality of the lime by careless or wrong use of reinforced draught. First, if the heat is made too intense, it may cause a chemical union of lime with the silica impurity of the stone which forms a lime silicate as in cement manufacture. The reaction would result in hard masses in the lime and also in the formation of a silicate coat around the blocks of limestone, preventing thorough calcination of the interior with a result of underburned cores.

Second, the included moisture of the stone being suddenly changed into steam by the excessive heat would burst the blocks of stone into fragments and the expansion of the rock itself would bring about a similar result. Such changes would yield a lime composed of small pieces with much lime dust which chokes the draught in the kiln and also makes a lime not popular with the market demand.

There is also a possible third objection to the use of an excessive draught in that it would carry a portion of the ashes into the kiln there to be fused or included with the lime. If the ash is high in silica or alkalies, or sulphur, the trouble would be increased, and there is a general tendency to color the lime by this action.

In the air draught, compressed air is forced through a pipe to the fire-boxes of the kiln and increases the temperature by insuring complete combustion of the fuel, and further carries the flame and heat well up into the kiln. There is a marked saving in fuel and increase in capacity of the kiln. Against the use of forced air draught, it is claimed that the temperature is raised so high in the lower part of the kiln that the lime is burned too quickly causing the rock to break into small lumps which on exposure to the air rapidly slake. It is also urged that the air-blast introduces a large amount of air into the kiln and so slakes the lime. The ordinary slaking of lime on exposure to the air is due to the absorption of moisture,

PLATE XXXI.—Irregular Surface of Stones River Limestone as Shown by Stripping off the Red Clay Cover at National Limestone Company Quarry.

forming the hydrate. If dry air is used in the forced draught there could be no air-slaking, and even if the air was moist there would be no absorption of moisture at the high temperature of the kiln. Further the breaking of the lime into small pieces prevents air-slaking rather than increasing it, on account of the surface protective coat formed over the finer lime.

In the use of a forced draught it is important that the requisite amount of air should be used, an excess of supply will prove wasteful of fuel. The air should also be heated, or a considerable amount of the available heat of the fire will be consumed in heating the air. The admission of cold air below the grate-bars in the forced air draught is very wasteful of heat and also soon destroys the grate-bars.

In the Shoop kiln which is used in several plants in Berkeley and Morgan Counties, the cooling lime in the lower part of the kiln gives off heat which is drawn through an opening and passes up as heated air through the grate-bars, the ash pits being shut off from the outside air. A steam jet is introduced under the grate-bars, thus increasing the draught while the presence of the steam tends to prevent the too rapid combustion of fuel. The objection urged against this method on the ground that the introduction of steam will tend to slake the lime is not supported, for the lime at the high kiln temperature would not absorb moisture.

The Eldred process of burning lime with coal has been adopted by many of the large lime companies and they pronounce it a success. The object of the process is to secure a long flame with coal fuel, bringing the heat of the fuel well within the kiln instead of in the fire-boxes. It is thus aimed to regulate and control the duration of combustion by regulating the temperature and volume of the flame by means of a mixture of air and a natural gaseous diluent composed of the kiln gases drawn from the upper part of the kiln. These gases are neutral in being neither combustible nor supporters of combustion since they are poor in oxygen and can be mixed with sufficient fresh air to give the required percentage of oxygen in the mixture. The diluent gases act as a carrier of the heat of combustion, lowering the temperature of combustion but distributing this heat uniformly near the material to be heated. One ton of coal in this process is claimed to yield six tons of lime.

Producer gas is used in many modern plants for burning lime. It is in use at the Security plant near Martinsburg and has there proved very successful both in lowering cost of fuel and in increased capacity. In one of the plants in the Toledo district of Ohio, a month's run with producer gas used in the Bradley-Duff process, one pound of coal burned four pounds of lime, and in some other plants it is claimed the amount of lime was increased to five pounds. The coal is burned in this process in a gas-producer into which coal is automatically fed and a spray of air and steam spreads over the interior and the gas is carried in water-sealed pipes to the kiln grates. There is a great saving in fuel and also a saving in labor cost that amounts to about one cent a barrel in the Toledo plant. With cost costing $3.00 a ton, the saving in fuel and labor by use of producer gas would be about two cents a barrel of lime. A 1000-barrel plant would thus save daily $20 by its use. Such a producer-gas plant will cost about $25,000, and the interest on this investment would be five dollars a day, or a net saving of $15 daily on the installation. This size plant would be sufficient for ten kilns with production each of 100 to 125 barrels. The cost includes two producers 12 feet 3 inches in diameter and 11 feet 6 inches high, with water pan below 15 feet 3 inches long and 2 feet 4 inches deep, with all necessary piping to kilns and automatic rakers. The cost of the ten kilns ten feet in diameter and 35 feet high is estimated to be by contract $25,000. In the Toledo district, where the kilns are built by the company with their own men, the estimate of cost is given as $1,600 each for above capacity.

Kilns Used in Lime Manufacture.

Here and there over the eastern Panhandle area of West Virginia, the farmers gather up the loose blocks of limestone over the fields and burn them in a home-made kiln for use on the land as fertilizer. Such kilns are heaps of stone piled to a height of 10 to 15 feet and containing about 1,500 cubic feet, yielding a thousand cubic feet of lime in best practice. The stone is piled on a grate of wooden rails with large blocks of stone at bottom and to the top are inserted vertical pipes for the draught, while toward the sides and top smaller pieces are placed. The kiln is long and narrow and is drawn in toward the top so that it has a rounded cross-section. Coal usually of slack or low-grade is mixed with the stone and also wood is added, and the whole kiln plastered over with sod and clay except for various small openings which can be opened and closed to regulate the draught. The wood is set on fire and the kiln allowed to burn out which requires ten days to two weeks. Much of the lime so made is underburned and is of no use, but enough is usually obtained for the farm use. When the labor and fuel costs are considered, it is doubtful if there is much economy in this method except where the location is remote from a lime supply. The product is as a rule poorly burned and there is a large amount of waste.

On some farms the "dug-out" kiln is made as a permanent kiln and in a former day this was the universal type of kiln for the manufacture of lime and was then described as a modern form of kiln. This kiln was built against the side of a hill which was hollowed out to receive it. It was built of stone, square in form, with a road above where the stone and fuel were hauled and dumped in, and the lime was drawn below. In the early type it was filled with stone and fuel and burned and the lime and kiln allowed to cool. It was then emptied and the next charge prepared. There was a great waste of fuel in heating the cooled kiln each time it was recharged, but where one kiln supplied the demand for a period of weeks or months, and wood or coal was cheap, it served its purpose very well. There are a few of these kilns in various parts of the eastern Panhandle area but most of them have not been in use for years.

In a modified type of this kiln seen in the country, the stone wall is built up above the fire-box about one-half the height of the kiln, and the remainder of the walls are made of logs set square and plastered with mud. This method of burning lime for the farm is more economical than that of the temporary boulder kilns set out in the field described above. It might possibly be of profit for some of these kilns back from the railroad to be repaired and used at the present time. The kilns can be built at low cost when the other work of the farm is not pressing.

In the continuous kilns the lime is withdrawn from below, while new material is added at the top, the fires are kept up constantly and there is no interruption in the work except for repairs or to decrease production.

In the old type of square stone kilns, the height is 18 to 20 feet and the sides of the square 10 to 12 feet. The coal and limestone are added in alternate layers. At the bottom is a layer of wood, which fired starts the combustion of the lower layer of coal and the fire gradually works through the kiln. As the lower burned lime is removed, new layers of coal and limestone are added above. The kilns are cheap in construction, the process of burning is simple, and the lime is usually of good strength, but is apt to be dark in color from the ash. The layers of limestone are 12 to 18 inches deep and a kiln of about 1,400 cubic feet capacity will yield 900 cubic feet of lime in 24 hours.[1] It requires some care in the operation of drawing the lime from these kilns to secure a good product. If drawn too soon, the lime will be underburned, and if left in the kiln too long, the fire crowds toward the top permitting the lower part of the kiln to cool down. If the fuel is properly proportioned to the amount of layers of limestone, there will be no danger of overburning.

In the Jefferson and Berkeley Counties lime district, there are 20 of these stone-pot kilns which were used in the early history of the industry for building lime, but at the present time most of them are out of service, and the others are only used once in a great while for the manufacture of agricultural lime. Each kiln has a capacity of limestone for 300 to 325 bushels of lime daily.

Most of the kilns now in use are iron and steel shell draw-kilns. Some of these are constructed on various patents and

[1]Frasch, Mineral Industry, Vol. VII, p. 488.

are known by the manufacturer's name, while others are built at the plant after the designs of the company. The shaft of the kiln consists of an outer cylindrical shell and an inner brick cylinder composed of two or three rows of fire-brick, or of a row of red brick with an inner lining of fire-brick. Between the steel shell and the brick cylinder is packed non-conducting material, earth or ashes. The shape of the inner cylinder, the form of grates and fireplaces, and methods of draught, vary in different styles of kilns.

Most of the kilns used in the eastern part of West Virginia are of the Decker pattern, with the interior widening at the top and tapering at the bottom. They are usually six feet in diameter and 20 to 25 feet high with a daily capacity of 250 to 300 bushels of lime in 24 hours. Below the fireplaces the cooling part of the kiln in some types widens to eight feet in diameter. Coal is used as fuel and is burned in three horizontal furnaces built out from the kilns at points equidistant. In a few kilns there are only two of these furnaces.

The kiln-shed has three floors, the upper near the top of the kiln and is connected with the quarries by inclines. The middle floor is level with the coal bins and is the firing floor, while the ground floor about level with the floor of the freight-cars, is the drawing floor where the lime is removed and packed in barrels or loaded as bulk lime in cars. The daily capacity of the lime-kilns of Jefferson and Berkeley Counties is about 10,000 bushels or over 3,000 barrels. The description of the lime plants in this area is included with that of the quarries in the preceding Chapter.

Cost Data on Manufacture of Lime.

A ten-kiln plant with daily capacity of 1,000 barrels of lime would cost about $25,000 and at 6 per cent. interest would be at the rate of 0.50 cents a barrel for 300 days' work a year. The depreciation on this plant which should be good for at least 20 years would be 5 per cent. or at the rate of 0.42 cents per barrel, and repairs in addition to that included in depreciation would be about 0.10 cents a barrel.

A cost of 30 cents a ton for limestone delivered to the kilns is a liberal estimate and should readily run under that figure in good quarry operation. At this rate it would cost 54 cents per ton of lime or 5 cents a barrel (185 pounds net). The fuel cost with coal costing $3 per ton (1 pound of coal burning 3½ pounds of lime) would be 7.9 cents per barrel.

The labor cost would involve, in a ten-kiln plant, four men to unload coal from the cars and fire the kilns, five men to draw the lime and load in bulk on cars; a total of nine men at $1.50 a day or $13.50. There would also be a brick-mason at $3 for repair work and a foreman or superintendent at $4. A daily labor cost of $20.50 for 1,000 barrels or 2 cents a barrel. The total cost then would be:

Quarry cost per barrel of lime	$0.05
Fuel cost per barrel of lime	.079
Labor cost per barrel of lime	.02
Interest, 6 per cent., per barrel of lime	.005
Depreciation, 5 per cent., per barrel of lime	.0042
Repairs, per barrel of lime	.001
	$0.1592

This is practically 16 cents a barrel and is a safe estimate under the average conditions. A confidential report on costs at one Ohio plant showed their cost to be under 17 cents a barrel.

As to the question of profits in the lime business, much depends on the market conditions. There have been periods of time in the past few years when there was not enough lime to supply the demand in this section. Buyers had to wait thirty days for shipments, and at other times the kilns were largely idle for low demand. The prices also fluctuate to some extent and prices made to-day may be very different from those of the next month. At the time this report was written the wholesale price of lime at Baltimore was 35 to 40 cents a barrel and freight rate from Martinsburg was 10 cents a barrel which made the price at the kilns 25 to 30 cents. The Baltimore price was regarded as exceptionally low and at that time one order for 3,000 barrels of lime was placed in Pittsburgh at 57 cents per barrel. The freight rate to Pittsburgh from Martinsburg was 19 cents a barrel which would have made this order net at Martinsburg 38 cents a barrel, which would represent a very large profit over cost of production.

Such illustrations show the lime business to be one of very large profits if the output can be sold, but in certain seasons of the year the sales are light and as has been stated the market demand and prices fluctuate. With all these modifying conditions the profits in the industry would seem to justify a larger development than is found in this great limestone belt of Berkeley and Jefferson Counties.

The Valuation of Limestone for Lime.

Mr. J. S. Grasty of the Virginia Geological Survey gives a very interesting and valuable discussion of the valuation of limestone for the manufacture of lime (Rock Products, November 7, 1914, p. 30), which is here reproduced.

Limestones are usually impure and contain such compounds as silica, alumina, iron, and magnesia, in varying quantities. In the process of burning, a portion of the lime combines with these other ingredients and is thereby lost as lime for use in actual work. The total amount of lime carbonate should produce a given amount of lime oxide, but by the combination with impurities, it gives a less amount of oxide or quicklime. It becomes important, therefore, in selecting a limestone for lime manufacture, or in the purchase of lime on the market, to determine how much available lime is really present.

Mr. Grasty in the article quoted gives the various steps in the calculation of the factors to be used in the determination of the available lime. The factors so determined are as follows:

1. The amount of lime carbonate consumed in union with the silica, forming di-calcium silicate, is determined by multiplying the percentage of silica by the factor, 3.32.

2. The amount of lime carbonate consumed by the alumina, forming tri-calcium aluminate, is determined by multiplying the percentage of alumina by the factor, 3.00.

3. The amount of lime carbonate consumed by the iron, forming tri-calcium ferrate, is determined by multiplying the percentage of ferric oxide by the factor, 1.875.

By taking the total results from these three factors and deducting from the total lime carbonate given by the analysis of the limestone, the difference will give the total amount of lime carbonate really available for lime. A ton of limestone multiplied by this actual available percentage will give the number of pounds available lime carbonate. This product multiplied by 56 per cent. will give the weight of lime oxide which the limestone should yield.

To illustrate this method of determination of the value of a limestone for lime manufacture, two limestones will be taken from Berkeley County. The pure limestone is from near Martinsburg, while the other is from the Helderberg horizon:

	A	B
Lime carbonate	98.98	89.38
Magnesium carbonate	0.43	2.25
Silica	0.58	5.32
Alumina	0.13	1.20
Iron oxide	0.75	0.23

Using the above factors, we have:

Silica	0.58	x	3.32	=	1.92
Alumina	0.13	x	3.00	=	0.39
Iron	0.75	x	1.875	=	0.41
Total					3.72

98.98 — 3.72 = 95.26 per cent. of available lime carbonate. One ton (2240 pounds) x 95.26 per cent. = 2133.8 pounds of lime carbonate.

2133.8 pounds lime carbonate x 56 per cent. = 1194.9 pounds of lime oxide.

Taking the other more impure limestone, we have·

Silica	5.32	x	3.32	=	17.66
Alumina	1.20	x	3.00	=	3.60
Iron	0.23	x	1.875	=	0.43
Total					21.69

89.38 — 21.69 = 67.69 per cent. of available lime carbonate. One ton (2240 pounds) x 67.69 per cent. = 1516.2 pounds of lime carbonate.

1516.2 pounds lime carbonate x 56 per cent. = 849 pounds of lime

The pure limestone at Martinsburg would yield per ton 71 per cent. more lime oxide than this more impure limestone. This simple calculation will enable anyone to determine the value of their limestone for lime manufacture after they secure analyses.

Manufacture of Hydrate Lime.

Calcined lime leaves the kiln in lumps of varying size. When water is added to it, the lime oxide crumbles to a flour and the process is called slaking or hydration. The resultant product is a lime hydrate that is soluble in water. The volume and weight of the lime are much increased by hydration. In pure limes the increase in weight is one-third, and in magnesian limes the increase is 14 to 16 per cent.

In the old methods of hydration, the necessary amount of water or more usually an excess is poured over the lime in a wooden box and left until the lime is properly hydrated or slaked. When proper precautions are taken, the lime is uniform and good. Careless work will injure the product and result in inferior work. Too much water will give a nearly fluid paste of lower strength. Too little water added at first is apt to chill the lime in the process of slaking and give a granular product. Unburned cores and overburned lumps are removed by passing the hydrated lime through a screen in the end of the box. This will keep out the larger masses, but small nodules may pass through, and later on the wall will further slake and cause popping and blistering of the wall.

As a rule unskilled workmen are employed in this work of slaking and through carelessness or haste used in the work, a poor product may result. Experiments were carried on the line of making a hydrate or slaked lime that will be safe and uniform and could be sold to the plasterers for immediate use without going through the work of slaking in open boxes. There are a number of such processes on the market and the hydrate manufacture has become so successful that many markets now demand the lime in this form. The product is sold under various names, as, lime hydrate, cream of lime, limoid, enamel finish, Banner hydrate, etc.

The two methods that have perhaps attracted the most attention are the Clyde and the Kritzer. The Clyde system is installed at the Bakerton plant of the Standard Lime and Stone Company and also at the plant of the Harpers Ferry Lime Company. In this process the large lumps of lime are crushed in a rotary crusher or in Fuller mills and then elevated to bins over the hydrating machine. The crushed lime is drawn from the bins into a hopper scale in 1,000- to 2,000-pound lots and dumped into the circular rotating hydrator pan. Over this pan is an automatic water sprayer which uniformly sprays the lime with a weighed quantity of water, and the operation of hydration requires about one-half minute on pure or high calcium limes. Scrapers in the pans insure a complete mixture and the heat generated evaporates all the free moisture, leaving the lime as a fine impalpable powder with a maximum temperature of 200° F. After the hydration is complete, the lime rapidly cools and is dumped into conveyors to the screens which remove any large particles and any underburned or overburned pieces. The lime is screened to a fineness of 40- to 200-mesh as the market may demand. The pitch of the screen determines the fineness. After screening, the lime is elevated into bins from which it is drawn into barrels or sacks. The product is usually shipped in paper bags of 50 to 100 pounds. With some of the patent sacking machines, one man can sack and seal 60 tons daily.

In the Kritzer method, now used at the Blair plant, there are four to six horizontal cylinders, one above the other, and connected at ends with the next one below, the object of this arrangement being to secure a long cylinder for hydration and at the same time economize space. Within the cylinders is a screw conveyor which carries the lime forward. The lime enters the first upper cylinder and a vertical stack at this point contains a water spray some distance above the cylinder. The water falling down the shaft over a series of projecting plates mixes with the lime in the cylinder which is thoroughly mixed by the screw conveyor. This stream of water falling down the stack absorbs the dust so that this type of plant is less dusty than the other type. The water also condenses the steam from the hydrating lime and is somewhat heated which aids in the rapidity of hydration. The operation is complete when the lime leaves the last cylinder.

The cost of hydrating lime by these methods including crushing, hydrating, screening, and sacking and loading on cars, is estimated at 50 cents a ton, but the increase in weight of lime in the Toledo district on the magnesian limes at present prices would represent an added value of 83 cents a ton so that the cost of hydrating is more than compensated by the profit on the added weight. The present selling price of the Toledo hydrate is $5.00 a ton net, or $5.50 in paper bags which cost 50 cents to the ton of lime. The hydrate is shipped in paper bags holding 40 pounds each or in burlap bags holding 100 pounds. In the latter case, the bags are charged at 11 cents each which sum is returned on receipt of the empty bags in good condition. The price of Toledo hydrate in Baltimore is $5.50 plus $2.90 freight or a total of $8.40 a ton.

The Kritzer machinery complete for a one-unit plant with a capacity of three tons an hour or 72 tons daily (24 hours) is about $15,000. A two-unit plant with a capacity of six tons an hour or 144 daily would be about $20,000 and the necessary buildings would probably cost $3,000 to $4,000.

Advantages of Hydrate Lime.—Hydrate lime has some very marked advantages over the lump lime. Being in a flour, it will keep better by formation of surface crust, thus protecting the under portions. It is permanent in bulk, having passed through its expansive stage, and therefore can be placed in paper or other package without danger of breaking same. The lime is usually better slaked than by the old methods and is ready for immediate use. Its underburned and overburned masses being completely removed, it will make a safe wall. There is a saving in storage, handling, packing, and in freights by rejection of the waste portion in advance. The plaster made from it is very uniform in grade and character. It can not cause fires when water accidentally reaches it.

Ordinary lump lime varies in its weight per bushel according to its size of lumps, the amount of slaking that has taken place, and the nature of the stone from which it is made.

The weight assigned to a bushel of lime varies in different sections. The legal weight of a bushel varies from 72 pounds in Pennsylvania to 75 pounds in Ohio and Michigan, and to 80 pounds in Virginia and a number of other States.

Uses of Lime.

Lime is used in the manufacture of glass as one of the essential components, though limestone is also used in its place and is regarded by many companies as better.

Paper manufacture requires the use of lime in a small way in the purification of the rags, etc., but in a larger way in the manufacture of wood-pulp papers. In cleansing rags, 5 to 15 pounds of pure lime are required to 100 pounds of rags. In the manufacture of paper from wood-pulp, the sticks of timber are fed into a cutting machine and the chips are reduced by chemical solutions to a pulp which is rolled into sheets for use in the manufacture of various kinds of paper. There are two processes used in this reduction of the wood to pulp.

The **soda process** is used on poplar, cottonwood, basswood, and some hardwoods and is popularly regarded as making the best pulp. The wood chips are boiled in digesters with soda-ash or carbonate which is rendered caustic by use of pure lime oxide. After boiling for a number of hours, the pulp is washed, screened, and bleached with lime chloride. This process requires about 20 tons of lime with 55 to 60 tons of pulp. The large mills at Luke, across from Piedmont, manufacture 20 tons of pulp daily.

The **sulphite process** is used with spruce and hemlock wood and is in operation at Davis and Harpers Ferry, West Virginia, where 24 tons of pulp was made daily. Magnesian or dolomitic limes are required in this process, and for the most economical work the lime should contain over 30 per cent. magnesia. The wood chips are placed in the digester with milk of lime and sulphurous acid. Under high heat applied, lime and magnesian sulphites are formed which remove the tar and oils and soften the fibers. Magnesian sulphite dissolves the non-cellulose matter more completely than the lime sulphite, and gives a stronger and more rapid reaction with these woods than pure lime sulphite.

Sugar purification makes a small demand for pure calcium lime, but this material is now largely replaced by use of the mineral strontium. The pure caustic limes are used in soap manufacture, leather plants, to some extent in gas purification, and a number of chemical uses. There is a growing demand for lime as land fertilizer though in many sections ground limestone is preferred. The great use of lime is for mortar and plaster, and both pure limes and magnesian limes are used. Lime mortars have been replaced to some extent by gypsum plasters in interior work, the so-called hard wall plasters made from the sulphate of lime rock, gypsum, instead of from the carbonate of lime rock, and also replaced to some degree in exterior wall work by Portland cement. The variety of uses is described in Volume III of the West Virginia Geological Survey, where will be found a more detailed discussion of this subject of lime and limestones.

The eastern Panhandle area contains very large deposits of all grades of limestone. Limes of almost chemical purity can be made for industrial works requiring caustic lime. Magnesian limes can be made in all grades including pure dolomite lime with the very high magnesia percentage. The transportation facilities are of the best in all directions. Fuel can be obtained at reasonable cost and electric power is available.

CEMENT RESOURCES OF THE EASTERN PANHANDLE AREA.

Certain impure limestones when burned form a product which can be used under water, and therefore have hydraulic properties, and are called hydraulic limes and cements. They are also called Natural cements.

Portland cement is an artificial mixture of lime, silica, and alumina, burned at high temperature and the resulting clinker ground to a very fine powder. For good results, the proportion of the ingredients must be carefully determined, thoroughly mixed, properly burned, and finely ground.

The first Portland cement mill in this country was built at Coplay in Pennsylvania in 1872. During the next eight years the total output of Portland cement in the United States was 82,000 barrels. In 1890, it reached 335,000 barrels, and in 1900, was 8,482,000 barrels, which represented a very large growth, but in 1913, the production was over 92,000,000 barrels. The production was about 86,000,000 barrels in 1915. Forty per cent. of the total comes from Pennsylvania. Three-fourths of the total comes from five States — Pennsylvania, New Jersey, New York, Michigan, and Ohio.

Natural hydraulic cement was patented in England under the name of Roman cement in 1796, and was made in New York about 1820 and 1825. The impure limestone adapted to this kind of cement is not uncommon, but it is widely distributed. Such stone, however, is apt to vary in quality in the same quarry or even in the same layer from place to place. There are comparatively few localities known where large deposits of Natural cement rock uniform in quality can be found. At the Natural cement plants great care was required to properly sort out the material in the quarry. It was found that only certain ledges could be used so that one of these quarries consists of a series of openings separated by walls of rock which were not fit for this work.

POTOMAC CEMENT COMPANY. — Natural cement was made for many years at Roundtop, west of Cumberland, in Maryland. It was made at Cumberland and west of there at Cedar Cliff in West Virginia. One of the very old plants was at Shepherdstown in Jefferson County and operated under the name of the Potomac Cement Company. This mill, still standing in good condition, is located one mile east of town. It was built in 1826 as a flour mill, and about 1830 was changed into a cement mill, and cement made for use in the construction of the Chesapeake and Ohio Canal. The mill is a three-story brick building, 50 by 100 feet, and was in operation from 1830 down to 1900, when the owner died and the mill has not been in use since that time. The portion of the mill used for cement manufacture is 30 by 30 feet and is equipped with crushers and three runs of buhrstones, while the rest of the structure was for storage and supplies. The plant was operated by water-power from the Potomac. The dam furnished 1,000 horse-power and backs the water for five miles, giving water transportation through the river to the Potomac Canal and on to Washington. It is also close to the Norfolk and Western Railroad. Most of the cement made was shipped in canal boats holding 850 barrels. The name of the company was later changed to the Shepherdstown Cement Company. The freight cost to Washington by canal was 8 cents a barrel while the rail freight to the same point was 16 cents.

The cement rock was quarried and burned in six stone kilns, 21 feet high, 7 to 8 feet in diameter at the top and tapering to the bottom. Alternate layers of fuel and stone were added, and each kiln yielded about 50 barrels of cement a day, giving a daily capacity of 300 barrels, and the average production was 200 barrels (300 pounds net). It was estimated that 100 tons of coal would burn 7,000 barrels of cement in these kilns, and the cement cost in manufacture was about 1C cents a barrel.

The rock burned soft and not to a clinker so that it was readily crushed and ground. It was used in the locks of the Potomac Canal in 1832, in the great Boundary sewer in Washington, in the Army and Navy Building, and other prominent structures in Washington.

The composition of some of the Natural cement limestones is given in the following table taken from Gilmore's work on cements:

	Cumberland	Shepherdstown	Rosendale	Roundtop
Carbonate of lime	41.80	58.25	30.72	65.00
Magnesium carbonate	8.60	11.16	35.10	5.30
Silica	24.74	17.84	19.64	27.10
Alumina	16.74	4.60	7.52	1.50
Iron oxide	6.30	1.70	2.38	
Alkalies	6.18	not det.	4.10	0.30

The above analyses show that the Natural cement rock is high in silica and alumina, the so-called impurities in limestone. For lime or for flux stone this rock would be worthless, yet these impurities give the cement value to the limestone and made it at a former day the basis of a most important industry, an industry now largely replaced by Portland cement. The limestone carries a small proportion of alkalies which aided in the fusion, and they usually carry a large amount of magnesia which was at one time regarded as one of the important conditions for a Natural cement rock, yet the limestones at Cumberland and Roundtop, low in magnesia, also made a very good cement. Magnesia is apparently inert and does not add to the value of the cement rock nor detract from it. In manufacture of Portland cement, magnesia in large amount is injurious.

In burning these rocks, the carbonic dioxide is removed, and the lime combines with silica and alumina forming silicates and aluminates. The cements made from these Natural cement rocks have the following composition, the analyses being taken from the reports of Ohio Geological Survey and from Mineral Industry:

	Cumberland	Shepherdstown	Rosendale	Louisville, Ky.
Lime oxide	49.60	33.20	34.54	41.80
Magnesium oxide	3.76	12.56	21.85	16.29
Silica	28.30	26.65	22.73	24.40
Iron and alumina oxide	14.54	14.52	10.43	6.20
Alkalies	.....	.....	3.63	1.52

The Shepherdstown cement had a tensile strength neat without sand of 50 pounds in one day and 300 pounds in 28 days, and was slow setting. Its strength was equal to the best grades made in this country.

Quarry.—The cement rock forms a bold bluff along the Potomac River across the county road from the mill. The limestone belongs to the Elbrook Formation and stands nearly vertical with a height of 125 feet. The quarry-face is 57 feet across, but 15 feet is rejected as too pure for Natural cement. At one place is a six-foot ledge which burned to a hard clinker and so was not used and was named by the quarrymen the green rock. The exposure of vertical cliff runs for a mile and contains rock of varying composition in the different ledges, so that only certain portions could be used for this cement. A large amount of material has been quarried, but there is an

PLATE XXXII.—Washery Plant for Removal of Clay from the Crushed Limestone at National Limestone Company Plant.

st unlimited amount left that is suitable for the manu-re of Natural cement but this industry has been so greatly aced by use of Portland cement that it is very doubtful if imestone could now be worked with any great profits.

The composition of the limestone ledges near this mill is n in the following Survey analyses:

	No. 51	No. 53	No. 106	No. 107	No. 111	No. 112
carbonate	16.73	52.74	47.42	70.43	23.51	68.79
esium carbonate	21.99	19.06	29.78	11.39	26.42	17.04
ı	43.67	15.89	13.44	11.04	34.82	10.32
ina	11.55	5.58	5.68	2.20	11.92	2.79
oxide	3.29	1.74	2 06	1.65	3.50	.63
lies	2.61	4.92	.....	.....	.....	.....
ium	0.48	....	0.16	0.19	0.43	0.09
phorus	0.19	0.12	.....	.....	....	.....
	100.51	100.05	98.54	96.90	100.60	100.59

No. 51 is from the ledge of so-called green rock near the old mill, h is said to burn to a good Natural cement but forms a hard clinker.
No. 53 is about ten feet from No. 51, but slakes on burning and was in the later work of the plant.
No. 106 is the rock generally used at the plant.
No. 107 is from nearly vertical wall and a large portion has been re-ed for cement. Ten or twelve feet of this ledge remain in a wall 100 or more in height.
No. 111 is the cement rock just east of sample No. 51 and was in use.
No. 112 is from one of the older quarries and the one nearest town. quarry has been abandoned for a very long time, but was regarded xceptionally good for Natural cement.

The limestone represented by sample No. 51, the so-called een rock, formed a hard clinker on burning and it contains .22 per cent. of silica and alumina, while the other limestones th 13.04 to 21.47 per cent. of these elements slaked on burn-g. Limestone of sample No. 111 with 46.74 was claimed to rm a very soft clinker readily crushed, and possibly its mix-re in the kiln with other ledges with lower silica and alumina rought this result. Its composition would indicate that by self it would form a clinker like sample No. 51. Magnesia ins high in all these rocks while the lime carbonate varies in ther wide limits from 16.73 to 70.43 per cent.

The variety of limestones in this cliff in chemical compo-tion is large and some ledges are very pure carbonate rocks. everal analyses were made in the laboratory of the Survey s follows:

	No. 108	No. 109	No. 110	No. 114	No. 113	No. 50	No. 144
Lime carbonate	90.18	81.90	85.42	94.82	83.61	80.69	48.47
Magnesium carbonate	3.27	9.59	10.14	4.45	6.19	7.48	28.95
Silica	4.84	6.18	3.42	0.70	6.24	5.21	13.18
Alumina	0.91	1.57	0.59	0.08	1.17	3.90	5.88
Iron oxide....	1.03	1.03	1.03	0.82	1.23		2.45
Titanium	0.06	0.12	0.06	trace	0.04	0.12	0.23
	100.29	100.39	100.66	100.87	98.48	97.40	99.16

No. 108 is a blue limestone which is near the Natural cement rock 106.

No. 109 is one-eighth mile west of last, where the rock is greatly folded. There is a large area of this rock, but percentage of magnesia is high for Portland cement.

No. 110 was taken 300 feet west of last and probably represents same stratum.

No. 114 is from a rather pure limestone, two feet thick on outcrop, but there are a number of ledges in this section that appear to be similar to it.

No. 113 is the rock near town and extends over a large area around the town.

No. 50 is taken from the limestone two miles west of last and near western edge of the town and shows a similar composition.

No. 144 is one-fourth mile east of No. 113 and is west of the Natural cement quarries and it is a dolomite and in all probability a Natural cement rock.

A deep ravine cuts through the limestone just west of the first quarry, where sample 112 was taken, and this ravine has always been looked upon as separating the Natural cement beds from the main mass of limestone to the west. The few analyses made of this material seem to confirm this observation.

Portland Cement Resources.

No Portland cement is made in the eastern Panhandle area of West Virginia, but the area has an inexhaustible supply of materials adapted to this manufacture. Locations can be made with the necessary materials side by side. There are fine building sites, abundant water-supply, cheap electrical power, excellent railroad transportation to large markets over short distances. In fact the location is almost ideal for this industry, and for this reason an outline of the method of manufacture and a brief discussion of this subject will here be given. For more detailed data on this subject, the reader is referred to Volume III of the West Virginia Geological Survey on limestones and cement.

Portland cement is formed from a definite mixture of lime, silica, and alumina, burned to a slag-like clinker and ground to a fine powder. In order to determine the amount of ingredients required to make a Portland cement, various formulæ have been devised. There must be a source of silica, alumina, and lime. Clay or shale may be used as source of silica and alumina, and limestone for the lime. To determine the correct mixture, S. B. and W. B. Newberry in Ohio calculated from the composition of the cement a formula for the proportion of parts. This formula was slightly modified by Bleininger on the Ohio Survey, and it may be stated as follows:

Four and sixty-six hundredths (4.66) times the percentage of silica plus twice the percentage of alumina equals the number of parts of lime carbonate required for 100 parts of clay or shale.

The impurities, magnesia and iron, in the clay, if not enough to reject the material, are to be disregarded in the calculation. The lime impurity in the clay or shale can be calculated as lime carbonate and subtracted from the estimated amount required according to the formula.

The application of this formula may be illustrated by using the cement materials found near Martinsburg.[1]

The Martinsburg Shale has the following composition:

	Per cent.
Silica	56.67
Alumina and iron	26.58
Lime oxide	2.28
Magnesium oxide	1.94
Alkalies	4.04

and the limestone:

	Per cent.
Lime carbonate	96.82
Magnesium carbonate	1.29
Silica	0.69
Alumina and iron	0.62

The shale would require according to the above rule:

$$56.67 \times 4.66 = 264.0 \text{ parts;}$$
$$26.58 \times 2.00 = 53.1 \text{ parts;}$$

317.1 parts lime carbonate.

[1]Credit for the application is due Bleininger, Geol. Survey Ohio, series 4, Bull. 3, p. 236; 1904.

The shale contains 2.23 per cent. of lime oxide which must be deducted as lime carbonate, thus giving:

317.1 — (2.23 x 100 ÷ 56) = 313.1 parts of lime carbonate required.

The limestone contains silica and alumina which will combine with part of the lime present, so that the amount of lime really available will be,

96.82 — (0.69 x 4.66 + 0.62 x 2) = 92.37 per cent. lime carbonate.

The amount of limestone to be used for one part of shale is therefore 313.1 ÷ 92.37 = 3.389 parts, or 100 parts of shale would require 339 parts by weight of this limestone for a cement mixture.

By following this method of calculation, the proportions for the mixture can be determined for shales and limestones of different compositions. According to Mr. Richard K. Meade if there was no loss of material as dust during the pulverizing and burning of the raw material and the clinker and the raw materials carried only 5 per cent. of moisture, it would require 583 pounds of the raw materials to make a barrel of cement (380 pounds), but he states that few manufacturers use less than 610 pounds of raw materials to the barrel of cement, showing a loss of 27 pounds as dust, etc., per barrel of cement produced.

SOURCES OF RAW MATERIALS.—The lime may be obtained by use of marl, chalk, alkali waste, furnace slag, limestone. The supply of limestone and probably also of marl is abundant in this area. The limestone must be low in magnesia.

The rock used for the lime in Portland cement is usually too low in silica and alumina, so that other materials must be added to furnish the correct proportion of these elements. In selecting clays or shales for this work, they must conform to the following factors according to Bleininger in the Ohio Survey Report:

1. The clay or shale must have a percentage ratio of silica to alumina of from 3 : 1 to 4 : 1. If the clay is high in alumina, it sets too fast and does not attain sufficient strength. If too high in silica, its fusion point is raised requiring more heat and greater wear on the rotary kilns. The sum of silica and alumina in the hydrous clay should not exceed 87 per cent. and probably not be lower than 56 per cent.

The Martinsburg Shales have:

Silica	56.67	56.29	53.30
Alumina	19.52	17.85	18.16
Ratio of silica to alumina.........	2.90:1	3.15:1	2.93:1

These ratios are practically three to one and by actual tests have been found to be adapted to this manufacture.

2. The clay or shale must not contain so much magnesia that the magnesia content of the cement rises above 3 per cent. or at most 5 per cent.

3. The clay or shale should contain at least 3 per cent. of ferric iron oxide.

4. The clay or shale should be low in sulphur and not have more than one per cent. of sulphur in any form.

5. The material should be free from any irregularly distributed matter as concretionary iron carbonate, or lumps of lime carbonate.

Prospecting and Location of Cement Mills.

Every owner of lands on which supposed cement materials are located is desirous of realizing on this value, but cement mills can not be located in such numbers. Certain supposed locations are often without value for one or more of several reasons, while others may be especially adapted for development and capital is wanting and apparently can not be obtained. A very common question is whether on a given tract the materials are valuable for cement. It is therefore deemed of sufficient interest and value in this section of the State to include in the report on these counties, where raw materials are abundant for this work and with the many natural factors so favorable, a discussion of the subject of prospecting for cement materials and location of mills. This subject is reproduced from the writer's report on cements in Volume III of the Survey Reports.

As has been shown above the chemical composition of the materials to be used in the manufacture of Portland cement must be carefully determined in order to know whether the chemical constituents can be brought to the proper proportion by mixtures, or whether the percentage of injurious elements is too high so that the materials would have to be rejected.

The analyses for this purpose should be made by a good chemist. When the proportions of ingredients are found by such analyses, the adaptability for cement mixtures may be determined by the formulæ above and the five factors as listed. The hardness of the limestone, clay or shale will have some bearing on the cost of manufacture, as involved in power required and wear and tear on machinery.

In selecting samples for examination, it is a waste of time on the part of the prospector and the chemist to take a sample of material from a single piece of rock at a single place. It is not unusual for a fragment of rock, a few inches in diameter, to be sent to the Survey office with request for its examination as a cement rock, and a report on such a specimen would be of little value.

The area and thickness of the rocks should be measured and samples taken from various parts of the deposit. These samples should represent average conditions. A vertical section of the rock to be used may be selected and samples taken from top to bottom; these should be thoroughly mixed and divided, thus giving an average of the stone at that particular location. If the layers of rock show variations, each stratum should be examined to determine what may be used and what must be rejected, a condition which involves increased expense in the use of the materials and may prevent the development of an industry on such rocks. The sampling should be repeated at intervals throughout the area of the formation to be used.

The surface rock is very apt to differ from that at the middle or bottom. The rock may be valuable for cement in one place and vary in another so as to require very different treatment, or even be worthless. Extra precaution in sampling may avoid expensive mistakes later in the development.

A stratum of limestone a few feet thick even of the highest grade would not be sufficient for the establishment of a cement mill. The thickness and extent may be determined where ravines cut across the rocks or along steep hillsides where the rocks are exposed. Where the rocks are not exposed to sufficient depth, borings should be made. In the case of clays or even shales this is not difficult, pits may be sunk or auger borings made. In limestone, diamond drill cores should be obtained. Quarry openings may aid, but not for the whole area, unless they are numerous which is rarely the case.

In the manufacture of a barrel of cement, it is stated above 600 pounds of raw material are required, of which 450 pounds would be limestone and 150 pounds clay or shale. The weight of a cubic foot of Martinsburg Limestone is taken as 160 pounds after making allowance for loss in the operation of the quarry. The weight of a cubic foot of shale is taken as 125 pounds. An acre of limestone (43,560 square feet) one foot deep would contain about 7 million pounds of rock, or sufficient for about 16,000 barrels of cement. An acre of shale would contain about five and a half million pounds, or enough for 36,000 barrels of cement. A fairly large cement plant with a capacity of 2,000 barrels of cement daily, working 300 days a year, would require then an acre of limestone a year worked to a depth of 40 feet. It would also require an acre of shale worked to a depth of 17 feet. Cement mills can not be profitably located where the supply of materials will last less than 30 years, and location estimates that run 50 years and more are preferred. By the above estimates, the limestone tract should run in uniform material not less than 50 acres and the shale not less than 50 acres. If this amount is increased to 100 acres each, the proposition is made more attractive. If the rock has a heavy cover of soil or other rock materials, the expense of stripping may be too great for profitable work. The amount and character of this cover should be taken into consideration. The ideal location for a mill would be where both materials needed occur together and such associations are to be found near Martinsburg. If the two materials are remote from each other, the cost of transportation of the crude materials will be a detriment and may prevent the profitable location of a mill.

Fuel represents a very important item in the cost of manufacture of cement and not all coals are adapted to this work. Location of cement mills in sections remote from the fuel supply have a disadvantage over mills better located. Estimates on fuel vary from 30 to 60 per cent. of the total cost of manufacture. From the experience of one mill it required 200 pounds of coal to burn a barrel of cement and furnish the necessary power. Coal costing $3.00 a ton would bring the cost of fuel per barrel of cement to about 30 cents. The coal for cement burning must have a high heating power, low sulphur, and a high percentage of volatile matter. The coal is pulverized and fed into the kilns as coal dust under air-blast. It must generate sufficient heat (around 2000° F.), give a maximum temperature about 12 feet from the point of entrance, and preserve a high temperature well through the length of the kiln, leaving it at the stack with as little waste heat as possible. The fuel is thus burned in the kiln and the ash becomes mixed with the cement, so it should be low in ash and free from sulphur. The cost and character of the fuel become important factors to be determined. The standard coal used in the cement mills as far west as St. Louis and north into Michigan is the **Pittsburgh seam** from mines of the Fairmont region in West Virginia. The coal contains 53.83 per cent. fixed carbon and 37.47 per cent. of volatile matter.

The cost and supply of labor is another item of importance in cement manufacture, and amounts to 45 to 50 per cent. of the total cost. The plant should be located near good railroad facilities and the distance to large markets should be as short as possible. The Martinsburg area is only 75 to 100 miles from large city markets and tide-water.

Finally, it must be remembered that a Portland cement mill of good capacity is an expensive plant to build, requiring a large amount of capital, and it may be some time before good deposits of cement materials in favorable locations attract capital; but with the increasing demand for cement, the favorable locations will gradually be developed.

Process of Manufacture.

The materials from the quarry are crushed, in ordinary quarry crushers, to a gravel and then dried in rotary cylindrical driers. The shale or clay and the limestone must be thoroughly mixed. The proportions of the materials to be used are weighed on automatic weighing machines. The materials are mixed to some extent in weighing and in the screw conveyors carrying them to the grinding department, but the intimate mixture is brought about by fine grinding in the dry method, and by agitation in water in the semi-dry methods. After the materials are ground to the size of gravel, dried, and the proper proportions weighed out, the mixture is ground to fine flour in mills adapted to such work. The following mills are in use for this work: Millstones, Griffin mill, Kent mill, Ball mill, Kominuter, Tube mill. A description of these mills and their use will be found in Volume III of the Survey Reports.

The intimate mixture of ingredients for the cement ground to a very fine flour is then burned in kilns of several types, but the usual kiln is of the rotary type and most of the cement is now burned in this kind of kiln. The rotary kiln is a slightly inclined steel cylinder 60 to 150 feet long and 6 to 10 feet in diameter, lined with fire-brick, and revolving on rollers at a rate of one revolution in from one to three minutes. The kilns are made of uniform diameter throughout or with a tapering portion into the chimney. The inclination is three or four feet in sixty. The kiln is usually supported on rollers at two points and is revolved by a train of gearing. The 60-foot kiln will produce about 150 barrels a day using 120 pounds of coal to the barrel. The 150-foot kilns are said to yield 750 barrels a day with fuel consumption of 75 pounds to the barrel. The shorter length of kiln requires the high temperature through the length of the kiln, and the products of combustion pass out of the stack carrying a large amount of heat which is thereby lost. The longer kiln requires a larger amount of power and it is a matter of dispute whether sufficient advantage is secured in the very long kilns.

The material is fed by screw conveyor into the stack end of the kiln, and passes out at the other end as clinker varying in size up to two or three inches in diameter, into cooling bins or into elevators carrying it to cooling bins or towers. Theoretically 43 pounds of coal would be required to the barrel of cement, but practically about 120 pounds are used. The loss of heat is by radiation from the kiln wall, the escape of heated gases through the stack, and the hot clinker discharged with a temperature of 2192° F. removes a large amount of heat, and there is usually an excess of air in the air-blast with the powdered coal fuel which lowers the heating value of the coal. The temperature of burning in the kilns should be such as to produce a dense greenish-black clinker. Underburned clinker is brownish and soft, while the overburned clinker is fused and slag-like. The temperature used in the rotary kiln will vary with the materials and method of mixture, but is about 2192° to 2552° F.

The cement clinker is cooled in open or closed bins, in rotary cylinders, or in vertical towers. It must then be ground to a fine flour in similar mills to those used in grinding the raw materials. Cement specifications require very fine grinding, 95 per cent. must pass through a 100-mesh sieve. The ground cement is packed in barrels of 380 pounds net, but the universal practice in this country is to pack in cloth or paper bags holding one-fourth barrel each. The cloth sacks are charged in addition to the cost of the cement, usually 10 cents each, the money being refunded on return of sacks in good condition. Portland cement weighs when loosely thrown into the measure 70 to 90 pounds to the cubic foot, or when packed, 110 pounds.

According to Prof. R. C. Carpenter of Cornell University, the total power required to operate the machinery of cement plants will average very close to 1.5 horse-power for each barrel when rock is used. A 1,200-barrel plant would use 1,800 H.-P.; a 2,000-barrel plant would require 3,000 H.-P.

In Volume III of the Survey Reports is given a detailed statement of the cost of construction of a modern cement plant with a daily capacity of 2,000 barrels, and the resume of this cost is as follows:

Power house	$150,000
Raw material department	115,000
Kiln department	118,000
Clinker grinding department	92,000
Warehouse and equipment	38,000
General equipment	70,000
	$583,000

The cost of a plant of double this capacity would be about $1,000,000. In addition to this cost of the plant, there should be provided a sufficient working capital. It is thus seen that these plants are very expensive to build and require large capital, but the profits are good and pay large interest on the investment when the prices are good and markets call for the output. As in other lines of industrial work, there are periods of dullness and sometimes eras of price cutting, but under all conditions American cement plants in good locations with modern equipment are looked upon as good investments.

While chemical study of the Martinsburg Shales and Limestones shows that if combined in proper proportions they will make a cement probably of high-grade, the actual manufacture of the cement would give a better and more satisfactory proof. This has been done by parties interested in this work some years back and the results have been kindly furnished.

The cement had the following composition as compared with some standard cements on the market:

	Martinsburg.	Alpha.	St. Louis.
Silica	21.66	22.62	22.80
Iron and alumina	9.16	11.42	10.90
Lime oxide	63.78	61.46	61.50
Magnesium oxide	2.28	2.92	1.25
Sulphuric acid	1.71	1.52	1.40

By standard specifications Portland cement when tested neat, that is, without sand, should have a tensile strength of at least 50 to 100 pounds in twenty-four hours, and 100 to 200 pounds in seven days. When tested with one part cement and three parts sand, it should have a tensile strength of 25 to 75 pounds in seven days.

The Martinsburg cement made above showed a strength when tested neat in 24 hours of 300 pounds and in seven days, 895 pounds. When tested with three parts sand in seven days, it had a strength of 340 pounds. These results were averages of five trials, and show a cement of very high character. 95.2 per cent. of the cement passed through a 100-mesh sieve, and all tests showed a good quality. Its specific gravity was 3.17. Its initial set was in two hours, and final set in 5 hours and 54 minutes. There thus can be no question but that the Martinsburg materials will make a good Portland cement.

The Uses of Portland Cement.

The growth of the cement industry in this country has been one of the marked features of the mineral industry. In 1895, according to the U. S. Geological Survey statistics, 990,324 barrels of Portland cement were made in this country, and 2,997,395 barrels imported, making a total of 3,087,719 barrels used that year. Ten years later, in 1905, the production was 35,246,812 barrels, and 896,845 barrels were imported, but about the same amount was exported. The production in 1913 was 88,514,000 barrels. The cause of this remarkable growth in the cement industry has been the increased variety of uses, especially its use as a substitute for other building materials, lumber, brick, and stone.

One of the most important uses is for concrete which may be defined as a mixture of cement and aggregate composed of coarse and fine material. This aggregate may be cinders, sand, gravel, finely crushed rock, or broken rock. The proportions of the mixture will vary with the character of the work and the plans and judgment of the worker. The proportions vary in ordinary work from one part cement, two parts sand, and five parts broken stone; to one part cement, four parts sand, and eight or ten parts broken stone or gravel.

There are two methods of mixing concrete — the dry method where just as little water as possible is used in the mixture; and the wet method where an excess of water is used. In the dry method the mixture is usually consolidated by pressure or tamping. In the wet method, the concrete is poured into molds. Concrete building blocks are usually made by the dry method, and concrete foundations by both methods, but more usually by the wet method. Concrete is now extensively used for the foundations of large and small structures. It can be placed rapidly and cheaply and in a few days is ready for the superstructure. A concrete foundation setting as one piece makes a stronger building. Railroad bridge abutments and retaining walls are now largely made of concrete.

Cement finds a large use in sidewalks and is in demand for roadways. The manufacture and use of concrete building blocks have become quite general over the country. Practically every town and city in West Virginia has a branch of this industry, though the use of the blocks varies in popularity. The successful use of concrete blocks in so many towns and cities, the ease of manufacture, the low cost of equipment for the work, directions for the work calling for no experience, and the rumors of great profits, have led many people with little or no experience to enter the field, and by their careless work, resulting in low-strength blocks, have done great harm to the industry.

Reinforced Concrete.—In the construction of bridges, tall chimneys, large buildings, etc., the concrete is strengthened by metal reinforcement, and is then called reinforced concrete, armored concrete, steel concrete. Experiments show that the tensile strength of concrete is low, but the compression strength is high. The tensile strength of steel is high, and the adhesion strength of concrete and steel is over 700 pounds to the square inch, so that the two substances taken together make a very strong building material.

The method of reinforcing concrete consists of placing expanded-metal wire, or rods laid in the concrete. In beams the rods are placed in the lower part of the concrete body with ends near the beam end extending upward. Some engineers claim that the adhesion between the concrete and the steel rods is greater when corrugated, twisted, or deformed bars are used and the patents on reinforced concrete are usually held on the form of steel bar used.

In the construction of modern fire-proof buildings, it has been estimated that the use of steel concrete, in addition to its advantages of fire-proof character, rapidity of construction, etc., represents a saving of nearly 25 per cent. in cost. The construction of these large buildings of concrete has become the common method in our large cities and they require a large quantity of cement and have greatly increased the demand. In some of these large structures over 60,000 barrels of cement are used. The roofs and floors are made of concrete and some of the floor blocks span an interval 18 feet square and are only 4 to 5 inches thick.

Nearly every large city fire gives proof of the fire-resisting properties of concrete. In the great Baltimore fire of February, 1904, one of the concrete bank buildings was the only structure left in an entire block where the temperature of combustion was estimated at 3,000 degrees, and it was estimated also that this building could be repaired at about 20 to 25 per cent. of its original cost. After the fire one of the floors in this building was tested with a load of 225 pounds to the square inch, and the deflection was only one-sixteenth of an inch.

Concrete finds use in construction of high stacks and chimneys, and in arches and bridges. Concrete has been used in place of wood piles for supporting structures on ground not firm enough for safe foundations. This use is now very common because of the economy and durability of concrete piles. Experiments are being made on railroad ties of concrete, and they are in use to a limited extent. It is estimated that over 100 millions ties are used yearly on the railroads of this country, and the cost of wood ties has increased from year to year, with a growing scarcity of timber.

On the farm concrete is finding many uses. It is used in making fence posts which are durable and not destroyed by fire. Concrete silos are now common through the country, and concrete water conduits and troughs. It is regarded as especially adapted to sewers where it is more permanent than brick construction, and cheaper. It makes a smoother interior wall thus giving an unobstructed flow to the drainage. It is more water-tight and is less liable to damage and collapse through any excessive loads upon it. Modern dams are now constructed of cement usually reinforced.

The uses of concrete and therefore cement are steadily increasing, and it would require a long list to give all the applications of this useful substance which is an artificial mixture of common substances found in so many places. Some writers style this period of time as "The Age of Concrete."

CHAPTER XVII

CLAYS AND ROAD MATERIALS IN THE EASTERN PANHANDLE COUNTIES.

CLAYS AND SHALES.

Clay may be defined as an earthy substance composed of a base of kaolin, mingled with a greater or less percentage of mineral and organic impurities; therefore, possessing a variable chemical composition, and having certain physical properties, all of which determine its value or utility to mankind.

In the beginning of its history, clay doubtless came from certain silicate minerals, especially feldspar, components of the so-called hard or crystalline rocks. The feldspar family is one of many members and complex composition, made up essentially of the chemical elements, lime, potassium, sodium, aluminum, silicon, and oxygen. The potash feldspar (orthoclase) and those high in lime (albite) through alteration form the mineral kaolin which is the basis of clay. Pure kaolin is a white clay and is chemically a potash aluminum silicate which is mined in considerable quantity in a number of southern States and is used in the manufacture of fine table and ornamental chinaware. All snow-white clays are not kaolin and here and there over the eastern Panhandle Area are found small deposits of bleached white clay popularly called kaolin, but they usually contain too many impurities for this pure variety.

The various alterations of rocks under atmospheric and aqueous agencies are included under the term **weathering.** The great agent of change in the rocks in the surface portion

PLATE XXXIII(A).—Harland Spring under Hill of Conococheague Limestone.

PLATE XXXIII(B).—Old Natural Cement Kiln (1830) Shepherdstown.

of the earth is water with its included gases and acids. What is termed pure water in the earth's surface or crust is pure only by comparison. Even the water as it falls from the clouds and before it reaches the earth is impure, containing gases and dust. These included gases are powerful agents of change and their power is augmented by increase in amount on contact with the earth.

The water now reaching the earth becomes an active geological and chemical agent, both by direct wear on the rocks termed **corrasion,** and by its chemical action or **corrosion.** The gases and acids especially important in water as a chemical agent of change are carbonic acid (CO_2), oxygen, sulphur in form of sulphurous acid, the humus or vegetable acids.

Clay from a chemical point of view is kaolin plus a greater or less amount of impurities. A chemically pure clay would be a pure kaolin with the following chemical composition:

	Per cent.
Silica	46.5
Alumina	39.5
Water	14.0

Kaolin is smooth and soapy to the touch, has a strong affinity for water, and when pure is snow-white in color, but it is found in nature in a great variety of colors. The pure kaolin would be found near the original rock mineral from which it was formed.

As the kaolin clays are farther and farther removed from their original place of formation, they become more and more impure and vary from the type. When clay is subjected to pressure, it is forced together and consolidated, and if the consolidation extends far enough, the clay becomes laminated in structure, and is then called a shale. If the shale be further consolidated and altered by great pressure and heat, as in mountain-making movements, the shale is changed or metamorphosed into **slate.** Kaolin especially, and, to much less extent, shales when wet have a somewhat soapy feel and are often called locally soapstone. The true mineral soapstone is a very different substance and is a synonym for talc.

The clay after being transported from its original home, perhaps consolidated into rocks and these by weathering breaking down and again transported and the process often repeated as in the case with our sedimentary rocks, will contain a variety of impurities gathered along the way. These various foreign impurities not only alter the chemical composition of the clays, but exert an important influence on the behavior of the clay when it is molded, dried, and burned into useful products.

Silica is one of the essential components of the clay and ranges in West Virginia brick clays from 46.89 to 78.12 per cent. It has an important effect on the shrinkage of clays and if in large amount may also affect the fusibility. Alumina is another essential component of clays and ranges in West Virginia brick clays from 19.32 to 39.55 per cent. Iron is always present in greater or less amount and determines the color in most clays. The amount in the brick clays of this State varies from 0.94 to 10.73 per cent. The color of the burned clay-ware according to Ries depending on the iron is due to the amount of iron oxide present, nature of the oxide, temperature of burning, condition of the kiln atmosphere whether oxidizing or reducing.

Burning these iron clays at a low temperature will give the pale salmon-colored brick, and the higher temperatures will bring out the deeper red shades. In such clays the color of the ware is an index to the temperature used and therefore to the quality of the brick. Lime is found in some clays and shales, usually in the form of the carbonate and may be detected by adding hydrochloric or muriatic acid which will act on the lime producing effervescence due to the escape of the carbonic acid gas. If much lime is present it will lower the fusion point of the clay and make it difficult to vitrify a brick without melting it. If the lime percentage is three times that of the iron, the result will be a cream- or buff-colored brick. Lime varies in the clays and shales of this State from a trace to 10.94 per cent. Soluble salts and magnesia if present in any considerable amount are apt to make trouble in surface coats or whitewash on the ware. Brick walls thus after damp weather will sometimes be coated or streaked with white or yellowish surfaces.

Water exists in clays and shales in two forms, mechanically included or moisture, and the water of chemical combination. The mechanical water or moisture is found in the pores of the clay and as surface films around the clay particles. The percentage is variable, and depends on the amount of available water and the fineness of grain. A coarse-grained clay does not retain the moisture as readily as a fine-grained clay. When the clay is taken from the bank or mine, the amount of this moisture may reach 20 or 30 per cent., but on exposure to the air it loses a very considerable portion of the water. At the temperature of boiling water, all the mechanical water is practically driven off and the clay shrinks in volume.

Physical Properties.—Knowing the composition of the clay or shale as revealed by chemical analysis and the role of the chemical compounds, the value of the clay as a useful product for certain purposes can be approximated. But with this information alone, the knowledge of the true value of the clay would be quite incomplete, and might lead to troublesome and expensive errors. Clays capable of utilization must possess certain physical properties, some of which can be foretold by the chemical analysis, while other properties must be determined in a different way, by a series of physical tests. Only a few of the more important of these properties will be discussed in this place. For a more complete discussion of this subject of clays, Volume III of the Survey Reports on Clays and Limestones may be consulted.

Fusibility, or the change from the solid state to a liquid condition, becomes an important property in clays for economic use. Every mineral in a pure state and under uniform conditions has a definite fusion temperature. Clay, being usually impure, composed of kaolin and a number of additional compounds, would have a varying fusion point for its different components, so in burning a clay, fusion of the particles takes place at different temperatures, producing different results. This makes fusibility in clays a very complex subject.

The three important points in the process of clay manufactures are, the points of incipient fusion, vitrification, and viscosity. At a certain temperature some very fusible components of the clay will begin to melt and cement together the unfused portions, forming a fairly compact mass. This stage is that of **incipient fusion** according to Wheeler. Ordinary brick are not carried far beyond this point.

As the temperature is raised, other less fusible components melt and fill the pores of the product, making it a dense, firm mass, and this point is that of **vitrification.** If the heat be further increased, the various components of the clay may melt and the mass begin to flow and alter the shape of the product, the clay having now reached the point of **viscosity.**

In some very fusible clays and shales the difference between incipient fusion and viscosity is less than 100 degrees, while in other clays, it may reach 500 to 600 degrees. The amount of this difference is very important, for in burning a kiln of ware, it is difficult to control the temperature within narrow limits of range. If the difference in temperature is small between vitrification and viscosity, it will be difficult to vitrify the brick without melting the whole mass. The temperature of fusion of a clay will depend on the porosity, chemical composition, amount of fluxes in the clay, kind of fluxes, and size of particles.

The temperature of fusion of a clay may be determined by an electrical pyrometer which is rather an expensive instrument, or by the Seger cones. These cones are about two inches high, made of kaolin, feldspar, quartz, marble, iron oxide, etc., so mixed as to fuse at different constant points but a few degrees apart in temperature. They are numbered from 36 down to 1, giving a range of fusion temperatures from 3362° F. to 2102° F. Another series is numbered below 1 by prefixing a cipher (0) to each number from 1 down to 022 which has a fusion point of 1094° F.

In use a number of these cones are placed with the clay to be tested, and the fusion point of the clay is determined by comparison with the cone which is fused. The melting point of the cone is reached when its tip bends over and touches its base. When used in the clay plants, the cone representing the temperature desired for burning the ware is placed in the kiln, and also a few cones of lower fusing points, so that they may give warning of approach to the desired temperature.

The term shrinkage refers to the loss of volume on drying, **air shrinkage**, and the loss of vôlume on burning, or **fire shrinkage**. It is important for the manufacturer to determine the amount of air and fire shrinkage in order to secure a final product of correct and uniform size. The dies must be made sufficiently large, so that the burned clay ware after shrinkage may have the desired form and size.

Plasticity is the property whereby a substance may be molded or modeled. When applied to clays it also involves the further property of retention of the given form after the molding and modeling process is completed. In clays this property is only developed in the presence of water.

All finely ground substances show this property of plasticity to a greater or less extent. Fine sand shows a very low degree of plasticity. It can be molded when wet, but not in very good shapes without breaking, and the form is not durable. Certain clays show a very high degree of plasticity and are called plastic clays. Other clays are only slightly plastic. Pottery clays must be very plastic, while brick clays may have much lower plasticity.

Plasticity is a property of wet clay which permits it to be molded, while **bonding power** has a double significance, the retention of the molded form, when dry, and the ability to unite with foreign materials. The more plastic the clay, the better it retains its form, also the more plastic the clay, the more foreign materials can be added to the clay. While the two properties of plasticity and bonding power are different, they usually stand in close relation, and in some definitions of plasticity the two are confused when plasticity is defined as the property of clay whereby it can be molded and retain the form when dry.

The **density** of a body is measured by its specific gravity which represents the weight of a substance compared with an equal volume of water. It is a useful property in comparing relative weights of bodies. The specific gravity of the clays in this State so far as they have been determined ranges from 2.34 to 2.66. A cubic foot of water weighs 62.5 pounds, so these clays would weigh per cubic foot 146 to 166 pounds, when compact with pore space removed. The average weight of clays is taken at 125 to 130 pounds as the clay comes from the bank in air-dry condition.

There is a large variety of clays and shales used for different purposes. Refractory clays have the property of withstanding the effects of high temperatures, and are therefore valuable in work where such temperatures are used. They are used for fire-brick for furnaces, kilns, fireplaces, etc., for gas-retorts, and glass-pots. No clays of this character are known in the eastern Panhandle Area. There are, however, valuable deposits of semi-refractory clays and shales. The clays in this group are not used for fire resistance, but for ware which requires firm, tough body, with low water absorption. They are clays which vitrify, which means that under sufficient heat the clay partially melts and the particles are thus brought closer together, with a more or less complete removal of pore space. A good fire-brick is porous, while the vitrified wares, in contrast, are non-porous, or better, the pore space is reduced to a minimum.

The clays or shales for these uses must be fusible, but in order to be valuable must also have the points of incipient fusion and viscosity removed from each other by a sufficient number of degrees to enable the clay to be partially fused but not melt the product. This is very important for two reasons: First, it is difficult to determine in a kiln just when vitrification has gone far enough for a completed product, and to be perfectly safe it is convenient for the operator to keep the ware at this temperature for a time and yet not melt down the contents of the kiln; Second, the ware in reaching the point of vitrification must have sufficient strength to hold itself in shape even under the pressure of overlying layers. If the ware was completely melted it would lose the required form and size.

In the manufacture of paving-brick, clays and shales are used, and good paving-brick are made from both materials, though in many sections of the country, shale paving-brick are regarded as the best. In these days of strong competition, it becomes necessary to improve the grade of paving-brick as much as possible. Inferior grades have found sale, and find a limited sale at the present time, where the price is lower than the better grades, but this condition is becoming less and less true. Nearly all city specifications are now rigid, and when enforced will only admit the best grades of brick. It therefore becomes a matter of the highest importance to the paving-brick companies to know the characters of their clays and how to use them to the best advantage. Fusion, shrinkage, absorption, and other tests of clays in this day lose their theoretical character, and become very practical and essential.

In the manufacture of sewer-pipe, the clays must have about the same qualities as those used for paving-brick. The clay must be plastic and burn to a dense, smooth body. The shrinkage must be low in order to produce a uniform product, and avoid cracking and warping. While the color is not important in determining the useful qualities of the pipe, it has an important influence on the sale, as the trade usually demands a dark, uniformly colored ware. There must, therefore, be the requisite amount of iron to produce this result. Sewer pipe is usually salt-glazed, which requires enough free silica to decompose the salt.

In the manufacture of roofing tile, the clay must vitrify and form a dense and tough body. It must give a good color and have a low air and fire shrinkage, as the thin plates are apt to warp and destroy the shape of the tile. The finished product must be light in weight, true in shape and possess strength, so that it can be handled and shipped without breaking.

Stoneware is a partially vitrified product which is burned and glazed before removal from the kiln. On account of the demand for this ware in household use, it is made in all sections of the country. With the number of clays adapted to this work in this State, it is strange that there is only one plant in operation and most of the stoneware is shipped in from other States.

The properties required in a stoneware clay according to Wheeler are: 1. The clay should be very plastic; 2. It should be free from coarse sand or other foreign matter; 3. It should be as free from iron as possible; 4. It should burn to a close incipiently vitrified body at a temperature less than 2200° F.; 5. The clay should have a range of at least 200° between the point of incipient and complete vitrification; 6. It should be capable of drying and burning at moderate speed without the addition of grog (burned clay); 7. It should form a tough and strong body when burned; 8. It should be free from carbonates, sulphates, and other salts that are liable to cause blisters in burning.

In the group of non-refractory clays are included the common pottery clays, and the clays so valuable for structural work. For the finer grades of pottery only the best and purer clays can be used. In the manufacture of flower pots and various forms of earthenware which is softer and more porous than stoneware, low grades of clays are used. They are burned at low temperature and form the porous body. Many of the common brick and tile clays are adapted to this purpose.

The building brick and tile clays are usually impure, more or less sandy clays with kaolin base low in quantity, and the color determined by the amount of iron. Practically all the clays and shales of this State burn to a red color which may vary from place to place in shade of red. As a rule they are not adapted to the production of a vitrified body, fusing rapidly at elevated temperature and so twisting out of shape and running together. The clays are used for products burned at moderate temperatures, fusing in the neighborhood of 1800° F. They vary in plasticity, shrinkage, porosity, etc. The better grades may be used in the production of high grades of pressed front brick or worked into ornamental patterns. They may be coated with a glaze, burning into enameled brick for interior and exterior work. Terra cotta is made from carefully selected clays which give uniform color, strong body, and burn without checking or cracking.

In the eastern Panhandle area there is a variety of shales and clays which by development would become very valuable. There are no fire clays and no kaolin or fine white china clays. There are, however, good stoneware pottery clays, clays and shales adapted to the manufacture of a very high-grade paving and ornamental brick and tile, and common building brick. The area is close to eastern markets which are now supplied with these materials from States to the west and this brick is hauled by long freight across this State to the eastern markets. There are several small brick plants in the area and only one large one. The freight rates to the eastern cities are almost half those in force from the western centers now supplying this trade.

Prospecting for Clays and Shales.

Clays and shales are found in practically every section of the eastern Panhandle Area in deposits of greater or less extent and of variable quality. A very small fraction of these deposits will ever be used, and only the best are worth an investigation. There are so many of these deposits that those remote from the railroad will be of little value. It does not pay to construct long switch connections for a brick plant when the materials can be found so close to the main line as is the case over this area. When a clay or shale deposit is located in a section where it might be utilized, its extent should be determined. This may be done by digging pits to find the thickness or by boring with an auger. If of shallow depth, it will hardly pay to develop. Its area or surface extent may be determined by following the stratum from place to place in ravines where the streams have exposed the material, in railroad or wagon-road cuts, in wells, or by digging ditches and trenches. Some judgment is here required to be sure the clay is continuous from one exposure to another, and it should be tested in these places to determine whether the quality is sufficiently uniform.

The amount of cover or overlying material and its nature, whether hard or soft, is important in determining the value of the clay. Only clays of the highest grade will pay the cost of tunnel or entry mines. Such mining of clays is avoided as far as possible on account of the expense and danger involved. If the cover is very thick, or contains hard rock layers, the expense of removal of the useless material will be too great to permit the working of the clay.

The relation of the deposit to water conditions should be determined. If it lies in a low valley where the pit would be filled with water in wet weather, or where the natural drainage would collect in the openings, there would be added the expense of pumping, which may be prohibitive for profitable work. On the other hand, there should be a sufficient supply of water present for the uses of the plant. Labor conditions, cost of transportation by water or rail to good markets, supply and cost of fuel, must all be considered. There is a more or less popular impression that the valuable materials for brick and tile must be present in the form of clay, so in prospecting, shales, or soapstones as they are locally called, are neglected. Shales often make better brick and tile than clay, but not all shales are adapted to this work any more than all clays. Two shales may look to the eye the same and yet one make a good brick and the other be worthless.

In sampling clay or shale, care should be taken to secure an average lot. If a pit is sunk, samples should be secured from top to bottom, and also from a number of pits removed from each other. The sample lot should represent an average of the tract to be developed. The large quantity thus obtained is then ready to be tested at some brick plant or pottery where it can be made into ware and burned, and the character of the product determined. A brick made from a few pounds of clay taken from some one spot does not establish the character of the clay, though it may give some indication of its value. Most brick machinery companies maintain testing laboratories where this work can be done at very reasonable cost. To illustrate how difficult and even impossible it is to judge of the value of a clay or shale by the eye, one trained clay-worker sent to the Survey a sample of No. 1 fire clay which showed on analysis 16.74 per cent. of fluxing elements. Very few clays in the State would equal this clay in fusibility, and it was worthless for that purpose.

It must be kept in mind that mere surface examination will not prove their value; chemical analysis is not enough; the clays and shales must be tested physically, and they must also be actually worked into finished products to determine their real value. Without this preliminary prospect work, the clays will not be available for the tests. The clay or shale must make a high-class product, but its extent, thickness, amount of cover, surrounding conditions, must be determined by very careful prospecting.

A few simple tests may prove valuable in this prospecting work. 1. A small lump of clay may be roasted in a blue gas flame as in a gas stove; if a red or brown color be given to the clay, the percentage of iron is high, probably four per cent. or more.

2. By tasting the clay, bitter salts may be detected, or they may occur as white coatings on the outcrop of the clay in the bank. These salts are apt to form whitewash coats on the finished brick, injuring their appearance. By crushing the clay in the mouth, the sand may be detected by the grit against the teeth, and a rough determination of the amount may be made.

3. The plasticity of the clay may be approximately determined by working the moist clay in the hand. A pottery clay may be tested by working the wet clay into shape and noting whether it retains the form when dry.

4. A rough brick of small size can be made and easily dried, and an approximate determination be made of its shrinkage. If it shrinks out of shape, cracks, or crumbles when dry, its value is very doubtful. In this test the clay should be ground fine, thoroughly tempered with water and dried slowly.

5. Carbonate of lime if present can be detected by placing a lump of the clay in hydrochloric acid and noting if there is any effervescence. It is not always possible to predict the color of the burned ware from the color of the clay. Red clays will usually burn red, blue clays may burn red or buff. Dark or black clays are usually high in organic matter which burns out and the ware may be red or buff.

6. The slaking of clays or the crumbling down in the process of tempering is tested by dropping a lump of clay in a cup of water. Some clays slake in a very few minutes, and so are easily tempered. Shales usually slake only after a long time, and require fine grinding. These various tests can be made by any person and while not conclusive, afford a basis for an approximate opinion on the nature of the clay.

Process of Manufacture of Brick and Tile.

The process of manufacture of the various clay products in considerable detail will be found in Volume III of the Survey Reports. In this place only an outline of this manufacture will be given as applying to the present brick plants in this area and to possible new ones that will in all probability be built.

The clay or shale is mined in surface pits usually, and is hauled to the plant by scrapers or dump-carts in small plants, and by small cars on a track by horses or cable in larger works. In the location of a clay-working plant, it is very desirable to have the plant and clay-pits near together and so decrease the cost of haulage. They should, however, be far enough apart to avoid danger to the plant and workmen from blasting and also from the caving of the bank from the effects of blasting and weathering. Rock slides which sometimes occur in clay and shale quarries should not endanger the foundations of the plant.

The clay or shale from the pits consists of coarse and fine material and must be brought to a uniform product by crushing. Another important result of crushing is the more thorough mixture of the materials, as the clay or shale may vary somewhat in different parts of the openings. Brick made from variable clays not thoroughly mixed would differ so much in their characters that it would be difficult if not impossible to mold them uniform, in drying they would shrink to different degrees, and in burning they would not vitrify equally. The result would be different sized, colors, and hardness in the same kiln of brick. If the clay is hard and usually in shales, crushers are required, but if so the material is finally ground in dry pans. If crushers are not required the dry pans alone are used.

The dry pan is a heavy cylindrical metal pan with a floor of screen plates over which roll two heavy wheels or mullers. The pans in very small plants may be only five feet in diameter, and they are made up to 12 feet, while the usual size is nine feet. The bottom plates have perforations usually about one-eighth inch diameter through which the ground clay passes. In a nine-foot pan the mullers are 46 to 52 inches in diameter and weigh three to four tons each. In capacity such a pan will run 25,000 to 60,000 brick in ten hours. The clay from the crushers and dry pans is carried to the screens and storage bins by conveyors. These labor-saving devices are used wherever the material is to be removed from one part of the plant to another.

In the process of clay manufacture, it is necessary to develop the plasticity of the clay by adding water to it, and to bring the whole mass to a uniform condition. The operation is called tempering. In pottery manufacture, this work is done in a wet pan which is similar to the dry pan only with solid floor in the pan. In brickmaking the pug-mill is used as also in the further tempering in potteries. The pug-mill is a rectangular wood or iron box varying in length up to 18 feet, the usual size being eight to ten feet. Through the center passes a horizontal shaft to which are attached 30 to 36 pugging-knives which are set at an angle along a spiral line so as to work the clay toward the discharge end. The clay is added through a hopper at the other end and water flows in through a pipe in amount as determined by the operator. A nine-foot mill will temper an average lot of clay in ten hours sufficient for 30,000 to 45,000 brick. The work of these machines is continuous and they afford a ready control on the tempering process.

After the clay is thoroughly ground and tempered, it is ready for molding into required shapes. In the small brick plants the molds are small wooden boxes and the molding is done by hand. In other plants soft mud machines are used, but in all the larger plants stiff mud machines are in use. In this method the clay is worked into a stiff mud which is more or less plastic but not pasty, and this mud is crowded through a die forming a bar which must be stiff enough to hold its shape even when subject to strain. Most of the modern machines are operated by an auger. The auger machine consists of a short pug-mill, the knives attached to a horizontal shaft which terminates in an auger. The tempered clay is fed into the machine through the hopper. It is there crowded forward by the revolving knives to the auger which presses it through the die, issuing as a compact bar of clay. If the brick are to be side cut, this bar has the length and width of the brick. If end cut, the bar has the width and thickness of the brick. In the ordinary size auger machine, the clay chamber is 24 inches in diameter, the shaft carries six double pugging-knives and an auger 8 to 18 inches long. Such a machine will make 4,500 to 6,000 brick per hour, requiring 40 to 60 horse-power and weighs six to seven tons.

The clay worked by the auger machine has a tendency to become laminated, which is in part removed by the pressure in forcing through the die. Very plastic clays will retain this structure and are not adapted to this process. Some clays to avoid this lamination require a longer or shorter auger, a longer or shorter space between end of auger and the die. It thus requires experiments to test the correct arrangement for different clays. Friction caused by the clay passing through the die will make the edges furred or rough unless overcome by using water, steam, or oil, as a lubricant in the die. Experiment is again required to find which method of lubrication is best. The clay bar is carried from the die on a belt conveyor to the cutting table which is close to the brick machine, where it is side or end cut by wires fastened to a steel frame and operated by hand or is automatic in action.

Paving-brick are usually repressed and some companies repress the building brick on machines of heavy construction designed for this work under high pressure. The object of repressing the brick is to make the brick denser, to stamp trade-marks or the name of the company or brick on one side, to give smoother surfaces and shape the corners and edges, and to obliterate the rough wire-cut edges or sides, and to mark one or both sides of the brick by special patterns as in paving block and some sidewalk brick. It is very doubtful whether the repressing of a brick adds any to its strength, in fact some engineers claim it lowers to some extent the strength.

The green brick from the machines or the pottery ware must be dried before entering the kilns. This is done in open yards by the sun in some small plants, on drying floors, or in tunnel driers heated by hot air or steam. The average amount of water in 1,000 standard size brick made from the average clays in this State would contain about 20 per cent. of moisture or about 1,400 pounds while in paving-brick there would be about 2,500 pounds of water to the 1,000 brick to be removed usually in 24 hours. The two important factors in drying brick are heat and circulation of air.

In most of the larger brick works, the brick are dried in progressive tunnel driers. The tunnels are 80 to 120 feet long, about five feet high, and same width, with tracks on the floor connected with the molding room. A series of tunnels is made side by side under one roof and heated by hot air or steam. The car of green brick is placed in the drier at the cool end away from the entrance of the heat. The next car pushes the first forward and so on until the car of brick dried is crowded out at the other end and is ready for the kiln. The car of brick thus moves progressively from cooler portions of the drier to the hotter portions and is gradually heated. In most modern plants the heat is drawn from the cooling kilns by fans and then forced into the tunnels. This method supplies cheap heat that would otherwise go to waste and also reduces the time for cooling the kilns. These driers are made with a capacity of 40,000 to 250,000 brick.

After the brick are thoroughly dried, they are removed to the kilns. The burning of brick in the kiln has been divided by Orton into three divisions corresponding to the important reactions at different temperatures:

1. **The Dehydration Period** which represents the dissociation of materials which are unstable at high temperatures, and the expulsion of the volatile portions from the mass of the clay. At this stage there has been little or no fusion of the particles of the clay, the hardness is very little higher than that of the dried brick, and the color, if iron is present, is a pale red. Brick removed from the kiln at this point would be useless.

2. **The Oxidation Period.** Now occurs the transformation of the non-volatile elements from less stable into more stable forms by absorption of gases from without the mass, especially oxygen. At the end of this period, the brick will have a uniform color from surface to center, there will be no cores of different shade if the operation is complete. The brick will be somewhat harder than before and fire shrinkage has commenced but so far is low. The brick at this point is not a salable product.

3. **The Vitrification Period.** In this period the amalgamation at an elevated temperature of the various residual inorganic substances left by the two preceding reactions is completed into a more or less perfect silicate compound. The stages of this period are incipient fusion, vitrification and viscosity or fusion. As the temperature is raised in the kiln, the product becomes denser and stronger reaching a maximum at a certain temperature varying with the nature of the clay, and then begins to fall until there results the brittle, often vesicular useless slag. This is therefore a most important stage in the burning, for the kiln operator must bring a kiln of paving-brick as near this maximum as possible and not carry the temperature over to the viscous state. Ordinary building brick are usually brought to the stage of incipient fusion.

The successful kiln burner must understand the nature of his clay and the changes which take place in its burning. He must be prepared to control the fires and drafts to insure complete oxidation increasing the kiln temperature for vitrification. He must know how to bring the ware to the correct temperature where vitrification will take place with the maximum

PLATE XXXIV(B).—Natural Cement Limestone Quarry in Elbrook Formation, One Mile East or Shepherdstown.

PLATE XXXIV(A).—Old Natural Cement Mill East of Shepherdstown. (Top).

strength of product, and not carry it too far where the ware will be softened and lose shape and strength.

Clay wares are burned in kilns which vary in shape and design according to the kind of ware and the ideas of the designer. Brick are usually burned in one of two types of kilns, **up-draft** and **down-draft.** The former are usually rectangular in shape and the latter usually round. In the up-draft kiln the heat passes from below upward and out at the top of the kiln, bringing the highest temperature near the bottom. In the down-draft kiln the heat passes through vertical flues or chimneys to the top of the kiln and passes out through flues at the bottom, bringing the highest temperature near the top of the kiln, and also distributing the heat more uniformly through the whole kiln. Both types are used for building brick and the second type for vitrified brick.

The up-draft kilns are in common use in the State for burning building brick. The brick are placed in the kilns 32 to 42 courses high and the kilns are made with 9 to 24 arches, holding 140,000 to 400,000 brick, which are burned in seven or eight days and cooled in six to eight days. The circular down-draft kilns in this State are made 26 to 30 feet in diameter. The 28-foot kiln will hold about 65,000 standard size building brick, or 35,000 pavers, and the larger size kiln will hold about 80,000 standard brick. The larger size kilns are more economical in fuel in proportion to the amount of product made.

In the past few years much attention has been given to the working of continuous kilns which have long been in use in Germany. In this type there is a series of compartments or separate kilns connected. In operation when brick are drying in one part, other parts are being burned and others are cooling. When one division is burned and the brick cooled, they are removed and the division filled with green brick. This German type is used to a very limited extent in this country. There are two types of continuous kilns now used in this country that are proving very satisfactory and result in great saving in fuel cost. One of these, the Yongren Kiln, is in use at the North Mountain brick plant near Martinsburg. The other type is the Haigh Kiln.

The Haigh continuous kiln is now in use at a number of large plants in this country and is held in high favor. It consists of a series of compartments each of which is fired independently. When burned the ware is removed from the outside and loaded into cars, while the compartment can be loaded with a new supply from the inner court of the kiln, the compartments being built on two sides of this court. The firing is done from furnaces on sides of the kiln and also fired from the top. The top firing is started before the side fires. The advancing heat from the other compartments brings the unburned brick in a given compartment to the settling point and through the water-smoking period. The fuel in the compartment is then added and it is claimed that the saving in fuel by this method is 50 to 60 per cent. One plant using this type of kiln stated that they used 1,275 pounds of coal per 1,000 brick in the down-draft kiln, and in this continuous kiln they used only 525 pounds for the same result.

In the No. 1 size kiln, which is regarded as the standard size for burning common brick, paving-brick, and hollow-ware, the sections are 15 feet wide, 12 feet long, and 11 feet 6 inches high. If made with 22 chambers, it gives a daily capacity of 30,000 to 40,000 brick, or 15,000 to 20,000 paving-brick, or 40 to 60 tons of fireproofing or hollow-ware. The Yongren kiln is described later in this Chapter under the heading of Adamantine brick plant at North Mountain.

Brick Plants in Eastern Panhandle Area.

The Cambro-Silurian Limestones in Berkeley and Jefferson Counties are overlain with a deposit of red clay. Its percentage of lime is low, while the percentage of silica is high, showing that it has not been formed entirely by the weathering of the limestone. It agrees more closely with the shales in its chemical composition. The deposit over the limestone at Bakerton is ten to twenty-five feet thick, and it is found over the limestone near Martinsburg, and near Charlestown and many other places. When wet it is very sticky and when dry shows a tendency to crumble like sand. It represents a source of large expense in the working of the quarries, and tests show that it does not make very high-grade clay products, though it is used for common building brick and is fairly satisfactory for this purpose.

The composition of this red clay at Bakerton and Charlestown is shown by the following Survey analyses:

	Bakerton.	Charles-town.	Martins-burg.	Valley Co. Charles-town.
Silica	55.43	54.35	72.10	46.21
Alumina	18.78	21.49	14.06	24.85
Ferric iron	7.06	8.00	3.60	11.81
Ferrous iron	0.15	0.00		
Magnesium oxide	2.59	0.79	1.12	0.85
Lime oxide	1.56	0.30	0.66	0.53
Sodium oxide	0.12	trace	.....	0.33
Potassium oxide	0.69	6.35	.....	3.20
Water	2.62	1.62	.....	2.89
Titanium	0.60	0.86	.....	.....
Phosphorus	0.60	0.09	.....	.....
Sulphur	1.05	trace	.....	.....
Loss on ignition	9.13	5.70	5.28	9.13
	100.38	99.55	96.82	99.80

The clay has a bright-red color due to the high percentage of ferric iron. It has a low percentage of lime even though it is so closely associated with limestone, and the lime will not injure the ware. The alkalies, soda and potash are high in the Charlestown sample and would make the clay fuse at low temperatures and this may explain the usually loose open texture and the brittle character of the brick. To make a good brick from this fusible clay requires great care in control of the kiln temperature. It vitrifies at cone 5 (2246° F.). Brick plants have been in operation on this clay at Charlestown and Shepherdstown.

There have been three brick plants at Charlestown operating for short periods of time and then abandoned. One of these plants was operated under the name **Charlestown Brick and Tile Works** and located just north of town. Brick were made at this place for eight or ten years to supply a local demand, but it has been out of commission for some years. The yard was equipped with a soft-mud machine consisting of a vertical press-box three feet in diameter with a horizontal 12-foot pug-mill, and operated by horse power. The clay was tempered in a ring-pit on the ground and the pug-mill, and burned in ordinary up-draft scove kilns.

The red clay in all these old yards is two to four feet deep resting on the limestone, and with large limestone boulders scattered through it. While the clay is of shallow depth, the available acreage is large. This red clay slakes in one minute and requires 32 per cent. of water to develop its normal molding consistency and it is fairly plastic. Its air shrinkage is 8 per cent. and the tensile strength reaches 153 to 167 pounds to the square inch. Its specific gravity is 2.61. It vitrifies at cone 1 (2102° F.) and becomes viscous at cone 5 (2246° F.), while the Bakerton with lower amount of alkalies vitrifies at cone 5 where the Charlestown clay is viscous. The total amount of fluxing elements in these clays which would include the iron, lime, magnesia, soda, and potash, is 12.17 in the Bakerton clay and 15.44 in the Charlestown clay which are high percentages.

The Valley Brick Company at the north edge of Charlestown has a very complete plant with dry pan, crusher, pug-mill, and auger machine of Freese pattern. The brick were dried in a 5-tunnel drier and burned in four down-draft round kilns, 30 feet in diameter. The red clay is used from over the Elbrook Limestone and the pit is 6 to 8 feet deep. Its composition is given in the preceding table of analyses. This plant has been idle for some time, but plans are under way to reopen it.

The Henson Brick Yard was located at the west edge of Shepherdstown, and also used the red clay from over the limestone. The plant was started in 1899 and made a very good quality of common building brick which may be seen in the State Normal School Building in the town. The clay was tempered in a soak-pit and molded in a Martin soft-mud machine of 12,000 daily capacity. The brick were dried in five shed pallet driers piled ten pallets high and holding 12,500 brick. The brick were burned with coal six to seven days in an up-draft permanent clamp kiln with eight arches, holding 140,000 brick. The plant has been abandoned for some time.

The chemical composition of these red clays, with the high percentage of silica, their location in depressions of the surface of the limestone and in the crevices of the rock, and the irregular eroded surface of the limestone floor, would indicate that the deposits of clay were transported, allied in origin to the river clays of the State.

The Buxton Brick Works is located one-half mile northeast of the city of Martinsburg and was built in 1895. The Martinsburg Shales are used, the surface weathered portions especially being mined. The shales are ground in a nine-foot dry pan, tempered in a horizontal 12-foot pug-mill, and molded in a stiff-mud and auger machine with a daily capacity of 30,000 brick which are side cut. The brick are dried in six dry sheds made with double sloping roof set on poles, with open sides, and holding 38,000 to 45,000 brick each. One shed is enclosed and provided with steam pipes in the floor for use in bad weather. The brick are burned seven to eight days with coal fuel in two up-draft ten-arch permanent wall kilns holding 206,000 to 212,000 brick. The brick are red in color, uniform in texture, hard and strong, and they have found a good market in local trade. The shale is worked in an open pit, three to eight feet deep, while borings have been made 16 feet into this shale. Only the softer, weathered portions are used, and masses of harder shale are left in the pit. Pure white clay streaks a few inches thick occur all through the shale, but are more frequent in the upper four feet. The shale comes to the surface. The chemical composition of the unaltered shale (slate) in the old Lovett slate quarry at a depth of 60 feet, and the weathered shale at the Buxton works are shown in the following Survey analyses:

	Lovett Quarry.	Buxton Yard.	Buxton near Plant.
Silica	53.30	57.75	61.19
Alumina	18.16	20.17	17.18
Ferric iron	1.95	7.00	9.04
Ferrous iron	4.58	0.33	
Magnesium oxide	2.65	1.22	1.98
Lime oxide	4.89	0.22	0.59
Sodium oxide	0.82	0.62	0.69
Potassium oxide	3.70	2.59	2.27
Water	0.68	2.75	0.39
Titanium	0.72	0.87	.....
Phosphorus	0.24	0.09	.....
Sulphur	0.77	0.00	.....
Loss on ignition	7.36	5.94	6.05
	99.82	99.55	99.38

The first two analyses show a loss of the soluble components with the resultant increase in silica and alumina in proportion to the other elements. The iron is oxidized in the weathered shale and appears as ferric iron. The percentage of fusible components has decreased from 18.59 in the deep shale or slate to 11.98 in the weathered shale. The silica-alumina ratio is practically the same in the two, 2.93 to 1 in the deep shale and 2.86 to 1 in the weathered shale.

The shale does not slake readily, requiring a long time. It takes 28 per cent. of water to develop its normal molding consistency. Its air shrinkage is 4 per cent. and the shale attains a tensile strength of 122 pounds to the square inch, and when well weathered this strength increases to 150 pounds. The shale vitrifies at cone 1 (2102° F.), with fire shrinkage of 11 per cent., and it is completely vitrified at cone 5 (2246° F.). The high percentage of fluxes is the cause of the low point of vitrification. This plant has for many years been the main source of supply of the building brick at Martinsburg.

To the north of North Mountain Station on the Main Line of the Baltimore and Ohio Railroad, seven miles **north** of Martinsburg, is the plant of the **Adamantine Clay Products Company** built in 1911 and using the Martinsburg Shale from a belt that outcrops along the east side of North Mountain. They have erected a modern plant equipped with stiff-mud auger, pug-mill, dry pans, etc. The brick are dried in a tunnel drier and burned in a Yongren continuous kiln fired with producer gas. The company so far has made a specialty of building brick and plans to make a paving-brick also.

The composition of the shales at this place is shown by the following analyses made by Dr. Heinrich Ries of Cornell University:

	A	B
Silica	62.88	62.36
Alumina	16.76	17.71
Ferric iron oxide	7.22	6.93
Lime oxide	0.12	0.10
Magnesium oxide	1.71	1.42
Potassium oxide	3.02	2.79
Sodium oxide	1.03	0.78
Water	6.93	7.22
	99.67	99.91

These two samples though taken some distance apart show a very uniform shale. The percentage of fluxes is 12.02 to 13.10, similar to the weathered shale at the Buxton yard. The silica-alumina ratio is higher, being about 3.65 to 1. The samples were taken from pits and represent the weathered portion of the shale. The iron is above the average percentage, gives a good deep color to the brick, and a deep chocolate-brown color to the vitrified product.

A mechanical analysis shows the size of the component grains of the clay or shale. Dr. Ries made the following mechanical analysis of this shale:

		Per cent.
Retained on sieve of	20 mesh	16.00
	40 mesh	38.00
	80 mesh	20.00
	150 mesh	17.00
Passed through the	150 mesh	9.00
		100.00

The portions retained on the 20- and 40-mesh sieves would be classed as sand coarse and fine. That on the 80- and 150-mesh sieve would be coarse clay, while that passing through the 150 sieve would represent fine clay. This shale therefore crushes to a fairly coarse clay with sand which is regarded as especially good in a paving-brick clay.

The shale represented by sample "A" is a soft buff shale which according to Dr. Ries' tests required 19 per cent. of water to form a normal molding consistency and was moderately plastic and had a tensile strength of 40 pounds to the square inch. It burned to a hard body of red color at cone 010 and 05 (1742° to 1922° F.) and vitrified at cone 3 (2174° F.) but was not fused at cone 5 (2246° F.). The air shrinkage was 3.3 per cent. and fire shrinkage at cone 3 was 13.3 per cent.

The shale marked "B" also a buff soft shale was more plastic and had a somewhat higher tensile strength of 68.7 pounds. Its air shrinkage was about the same, 3.5 per cent., and fire shrinkage at cone 3 was 16.9 per cent. It also vitrifies at cone 3 and is not fused at cone 5.

A sample of the black slaty shale which is found in the Martinsburg Shale formation was also tested and found to be of low plasticity and low tensile strength. This shale was past vitrification at cone 1 (2102° F.) and was fused at cone 3 (2174° F.). It also vitrifies very suddenly and is not very promising for brick material. The brick made at this plant confirm the preliminary tests here given, and the clay vitrifies to a good firm body of good color. Brick are shipped to Martinsburg and to eastern and southern cities. A large quantity was used on the new tunnel work of the Baltimore and Ohio Railroad near Pawpaw.

The Adamantine Company has worked out a considerable area of the surface weathered shales down to the black slate close to the plant with a depth of about 15 to 25 feet. The upper part of the bank shows it to be a slip from the mountain side with a mixture of shales and weathered clay. In the winter of 1914-15, a tunnel was driven west under the county road into the heavier part of the hill where a large open pit is excavated. The shales here are smooth yellowish-buff and some with bluish cast, and they are quite compact when fresh, but are readily crushed. They appear to be more even in texture and more uniform in composition than the shales and clay in the other pits near the plant, and they will probably make an even better product. The company is making good, solid building and sidewalk brick, and it also makes a very attractive front or ornamental brick in a variety of shades which have found ready sale in the eastern cities. Their rough tapestry brick has a pitted and somewhat corrugated side, and it is burned to a dark-brown color with tinges of black. It has a rock-face appearance and when laid in the wall gives a most pleasing effect.

The plant is of modern design, more so than many larger capacity plants in the eastern part of the country. The shales are easily crushed in a nine-foot dry pan, and thoroughly mixed and tempered in a 12-foot pug-mill, from which the clay is carried by conveyor to a Raymond auger brick machine (No. 888) which has a daily capacity of 60,000 brick. The solid clay bar from this machine is end cut by an automatic rotary cutting table, and the brick are then repressed on two Raymond repress machines.

The green brick are dried by hot air in a 12-tunnel drier. There is one track in each tunnel which holds 14 brick cars with 7,000 brick, so that the drier capacity is 84,000 brick in 24 hours. The loaded car from the repress machine is shoved to the cooler end of the tunnel, the next car crowds the first one forward, and so on until the tunnel track is full of cars. The next car added shoves the first car out with its load of dried brick, from the hottest end of the tunnel. By the use of several tunnels, the movement of the green brick toward the hotter zones of the drier can be delayed as long as necessary. There is thus a gradual drying of the product with the result of a better structure and greater strength. All shales and clays shrink on drying, and if this operation is too rapid, the shrinkage will crack and injure the brick structure. It is thus very important to have ample drying space and to use proper care in the manipulation of the drier, and of the brick in the drier.

The trucks or cars with the dried brick are then run on tracks to the kilns and set in them for burning. At this plant the Yongren continuous kiln of the Raymond Brick Company is used. This is a continuous kiln with 18 chambers at this plant, built nine on each side of a central court. The chambers open into the court from which the brick are taken into the kiln, and from which the burned brick can be hauled to the storage yard. They also open at the opposite end on a platform from which brick can be loaded directly into railroad cars.

These chambers or compartments are rectangular in shape with arched roofs, and in principle operate as a down-draft kiln. Each holds 50,000 to 55,000 building brick. They are fired with producer gas made in three large steel gas-producers where coal is used to generate the gas. A suitable pipe distributing system with regulator valves and dampers permits the deflection of the gas to any kiln chamber or group of chambers. There is also a series of pipes for carrying the surplus heat, or the heat from cooling compartments, where the operation of burning has been completed, to other parts of the kiln. This heat, which in the ordinary brick plant escapes into the air through stacks and is thus wasted and lost, is in this type of kiln saved. This heat can be carried in the pipes to a chamber filled with brick from the drier, which still contains a very considerable amount of water. This extra moisture can not be removed, practically or economically in the drier, but it can be removed in the kiln by use of this waste heat. This period of burning in the kiln is known as water-smoking, and is done in the ordinary type of kilns by slow fires continued for several hours with a resultant consumption of fuel. It is estimated by some manufacturers that 30 to 40 per cent. of the coal consumed in burning a kiln of brick is used during this water-smoking period. The continuous kiln as used at this plant is not only a great fuel saver; but it also permits such close regulation of heat in the kiln that the product can be burned at the correct temperature and held at that temperature for a sufficient length of time to secure the best results.

Sidings from the Baltimore and Ohio Railroad are arranged for loading brick from the kiln compartments into the cars, and for bringing coal convenient to the producers and drier. The machinery is operated by steam, and the drier is fired by coal furnaces. The buildings housing the plant are of heavy timber construction, and the entire plant is compact and well built. The buildings were completely destroyed by fire in the summer of 1915, but were rebuilt so that the plant was in operation by January, 1916.

The Martinsburg Shales at a number of localities are available for brick and tile manufacture and convenient to railroads. A few analyses of these shales and some of the clays as made by the Survey and others are here included. From the chemical composition, these shales and clays are adapted to the manufacture of good products, but it must be remembered that actual tests by making the products are necessary before the real value of the shales and clays can be known. The analyses then suggest favorable conditions and in the few cases where tests have followed the analyses they have proved the value of the material:

	No. 43	No. 58	No. 27	No. 90	No. 189
Silica	56.67	56.29	58.64	70.41	60.23
Alumina	19.52	17.85	18.06	10.20	18.98
Ferric iron	3.06	2.41	6.18	7.11	6.07
Ferrous iron	4.00	4.58	.....	0.45	0.39
Lime oxide	2.23	2.88	2.76	0.50	0.56
Magnesium oxide	1.94	2.63	2.61	0.58	0.86
Sodium oxide	0.96	1.02	.....	0.37	0.53
Potassium oxide	3.08	3.56	.....	1.73	3.06
Water	0.36	0.31	.....	1.82	2.37
Titanium	0.86	0.78	.....	1.20	0.89
Phosphorus	0.45	trace	.....	0.26	0.12
Loss on ignition	5.56	6.84	7.40	5.05	6.28

No. 43 is the shale near Berkeley Station on the Tabler farm, four miles northeast of Martinsburg.
No. 58 is the shale on L. Tabler farm, two miles from the last.
No. 27 is the shale two miles east of Martinsburg east of Opequon Creek.
No. 90 is the river clay sampled on the Walter Snyder farm.
No. 189 is the river or creek clay on the Wellschance farm northeast of Martinsburg, west of Opequon Creek.

The following analyses from a bore hole show the character of the Martinsburg Shales with depth in feet below the surface:

	0—24	24—84	84—140	140—200
Silica	57.96	56.06	50.30	55.46
Alumina	20.52	17.24	17.31	20.24
Iron oxide	7.42	7.42	6.41	4.94
Lime oxide	0.19	4.23	6.91	4.99
Magnesium oxide	1.56	2.84	2.60	2.32
Loss on ignition	8.06	8.74	11.16	8.78

The first 24 feet was very soft weathered shale and the rest was a hard black shale almost a slate. There is not as much change in composition as one would expect. The soluble lime and magnesia components are less near the surface while the iron is about the same except the lower percentage near the base of the section. With the steeply dipping ledges a vertical bore hole would not follow one ledge, but intersect a number of sloping ledges which might vary one from another in composition.

Two of the shale tracts near Martinsburg have been most carefully tested in the past few years by the writer for interested parties. The tests were carried on in the laboratory of the American Clay Machinery Company at Bucyrus, Ohio. One of these locations was on the Aler farm two miles southeast of Martinsburg. In that section there is a vast acreage of shales which show an excellent outcrop on the Aler and adjoining farms.

Pits were sunk on the Aler farm and the surface weathered shale as well as the more solid buff shale below the surface were tested, and it was found that by a mixture of these two shales a most excellent quality of brick could be made. The brick have a rich deep-red color most pleasing to the eye, and they vitrify to a dark-brown color, and if carried further have a black tinge. Tapestry brick with their roughened surfaces give a dark-velvet sheen, so much in demand in cities now for fronts of fine buildings and which command fancy prices. Flat floor tile and also hollow fireproofing tile in two-foot lengths were made without any indication of twisting or warping out of a true rectangular shape, and they had high strength. Vitrified paving-brick were made which withstood the rattler test required by city specifications with only 20 per cent. loss by the abrasion of the test.

These shales are well vitrified at cone 5 (2246° F.), and there was good range between vitrification and fusion. The tract is about one and a half miles from the Baltimore and Ohio Railroad but close to the National Limestone Company switch, and it was planned to use this line. The materials here are adapted to a broad line of structural clay building materials and the quantity of shales is practically unlimited, so that it forms a most promising location.

An analysis of the weathered shale below the surface on the adjoining National tract as made in the Survey laboratory shows the following composition:

	Per cent.
Silica	61.08
Alumina	18.21
Iron oxide	8.21
Lime oxide	0.35
Magnesium oxide	1.53
Potassium oxide	2.67
Sodium oxide	1.07
Water	1.86
Loss on ignition	5.21
	100.19

Another tract tested by the writer a few years ago was the **Myers and Houch farms**, just east of the Opequon Creek, on the Main Line of the Baltimore and Ohio Railroad, two miles east of Martinsburg. On these farms is a series of shale hills, 20 to 40 feet above the railroad level composed of buff flaky shales quite soft, with a level field below for the plant site which adjoins the right of way of the railroad and about same level. There is also an abundant water-supply either from the Opequon Creek or from the Tuscarora. The buff shales grade downward in the deep run cuts into a hard black slate. These are exposed in the lower levels near the Opequon and in one other deep run valley. Tests were made on the surface cultivated crumbly shale which is of shallow depth, on the more solid buff shale, and on the hard black shale or slate. The mixture of surface crumbly shale and the buff shale made a very satisfactory building brick and tile which, like the Aler shales had a good rich color and showed no warping. It likewise made a beautiful ornamental brick. These materials made from the two places could not be told apart.

The paving-brick apparently had a good firm body and structure and were well vitrified and of good color, but showed a tendency to become brittle on vitrification and so had a rattler loss too high to accord with city specifications. The vitrification took place at about cone 5, the same as on the Aler tract, but the range between vitrification and fusion is probably too small so that after vitrification the brick pass over to the partial fusion state before the kiln temperature can be reduced. Tests so far would condemn this shale for paving-brick at least as far as the surface weathered portions are concerned. No pits were sunk so that the shales below the surface were not tested and it may be that the more solid shales below the much weathered surface portion will be found suitable for this work. The shales are on the same belt as those southeast of town and the composition is very similar, so that they would be expected to burn in nearly the same way. The shales are, however, adapted to the manufacture of practically all kinds of structural materials.

The black shale or slate was tested and like the tests at North Mountain on similar material they were not satisfactory. It burns to a brittle body, its strength is low, and it is probably of little value for the manufacture of clay products. This result is very important in the location of clay plants, as this black shale represents the unweathered portion of these shales and shale pits when sunk deep enough will encounter this material, so that the working depth of the shales is limited by the zone weathering. This depth of weathering is not known, though in one boring east of town there were 24 feet of the weathered shale and then black hard shale. In estimating future supply for a brick plant, allowance should be made for a working depth of not over 24 feet, and in some places it is probably less. In some parts of the Martinsburg area, the black slate is found at the surface and in others only three or four feet below the surface. In the area tested it is known to be at least ten to fifteen feet in the excavations made and the bore hole would indicate it was 24 feet.

There should be then a larger acreage of shale lands than in other localities where the shale structure is different. In this area the working shale pits will be comparatively shallow and extend over large surfaces with the growth and development of a plant. Fortunately these larger areas are available, but sufficient land should be purchased to make the future supply for the plant safe.

The analyses of the weathered surface shale (88), the more solid buff compact shale below the surface (89, 90), and the hard black slate (91) on these Opequon tracts show the following composition as determined in the Survey laboratory:

	No. 88	No. 89	No. 90	No. 91
Silica	59.86	59.69	59.29	58.91
Alumina	18.42	19.49	19.56	18.23
Iron oxide	9.08	7.82	8.19	7.82
Lime oxide	0.29	0.25	0.52	1.82
Magnesium oxide	1.42	1.81	1.90	1.96
Sodium oxide	1.17	1.32	0.81	0.91
Potassium oxide	3.29	3.31	2.65	3.21
Water	1.40	0.90	1.41	1.25
Loss on ignition	5.51	5.55	5.43	5.46
	100.44	100.14	99.76	99.57

The Martinsburg field with its great supply of shales adapted to the varied clay industries, its location near main lines of transportation, and short distances to eastern large cities with resultant low freight rates, cheap electric power, abundant water-supply, ought to be one of the great clay-working centers of this country. It would be difficult to find more advantages crowded into a single area than are found here.

The profits in the clay industries are most attractive, even after making due allowance for times of dullness of market. A modern fire-proof plant equipped with the best of labor-saving machinery, with continuous kilns, and the purchase of the land, with a daily capacity of 60,000 paving-brick, or 100,000 building brick, would cost about $250,000, and if all the production was sold at current prices, the annual profit above all expense would reach $60,000. If by dullness of markets, low sales or other causes only half the product was sold, there would still be an annual profit equal to 12 per cent. on the investment. Such a plant would require about 70 men.

Other Clays and Shales in the Eastern Panhandle Area.

Clays suitable for stoneware manufacture are found at various places in this eastern Panhandle Area, and many years ago a plant was in operation at Martinsburg. These clays are along the Opequon and various other stream valleys of Berkeley and Jefferson Counties. There is a very good deposit on the Tabler farm near Tablers Station (No. 214), on the Snyder and Wellschance farms and other adjoining tracts on the Opequon. A search for these clays would doubtless reveal many good deposits. There is only one operating stoneware plant in this State and that is near Clarksburg, and yet there is the large market in the State and in the East. The cost of erection of such plant is not high and it should be a profitable industry in this area.

The composition of these stoneware clays is shown by the following Survey analyses:

	Snyder.	Wellschance	Tabler at Tablers Station
Silica	70.41	60.23	56.83
Alumina	10.20	18.98	21.78
Ferric iron	7.11	6.07	4.20
Ferrous iron	0.45	0.39	
Magnesium oxide	0.58	0.86	1.04
Lime oxide	0.50	0.56	0.90
Sodium oxide	0.37	0.53	0.35
Potassium oxide	1.73	3.06	1.58
Water	1.82	2.37	5.44
Loss on ignition	5.05	6.28	8.21

Physical tests were made on the Snyder clay which gave an air shrinkage of 5 per cent., tensile strength, 151 pounds to the square inch, or when weathered reaches 170 pounds. The clay is nearly steel hard at cone 05 (1922° F.), reaches incipient vitrification at cone 1 (2102° F.), and is completely vitrified at cone 5 (2246° F.), with a fire shrinkage of 10 per cent.

In the above discussion of the Martinsburg Shales, only one operating large plant and one small one were in operation, and only two other tracts were discussed because these were the only places where data on actual tests were available. With the large area of outcrop of these shales and near railroads, in fact, many of the railroad cuts are through this shale, there are doubtless many good locations where the shales would test out equally well.

In Morgan and Berkeley Counties is the great deposit of Devonian Shales described in the Chapters on these formations. Some of these are adapted to brick manufacture. It would require careful tests to prove the different locations best suited to this work, but a study of the chemical analyses of these shales gives much encouragement as to their value. These Devonian Shales are now in use at the large brick plants at Cumberland and Hancock, Maryland, where building and paving-brick are made. The successful growth of these plants in recent years is proof of the value of these shales.

The Devonian Shales outcrop along the Baltimore and Ohio Railroad from Hancock east to near North Mountain Station. Analyses were made of this group of shales in the Hamilton division, as found near Cherry Run town, and on the low-grade railroad line to the north of North Mountain. The composition is as follows in the first two analyses:

PLATE XXXV.—Tomstown Limestone with Crevices from which Iron Ore has been Removed at Orebanks, One Mile East of Bakerton.

	North Mountain.	Cherry Run.
Silica	62.18	62.78
Alumina	17.19	16.58
Ferric iron	7.05	3.52
Ferrous iron	1.36	4.76
Lime oxide	0.58	0.65
Magnesium oxide	1.01	1.70
Potassium oxide	2.78	2.78
Sodium oxide	0.57	1.09
Water	0.56	0.36
Titanium oxide	0.61	0.45
Manganese oxide	0.02	0.04
Phosphoric acid	0.20	0.22
Loss on ignition	5.36	4.36
	99.47	99.29

There are large areas of a very red shale in the Catskill Formation which outcrops around the mountain borders in Morgan County. In many places these shales are very sandy, grading into sandstones, but there are deposits of large size of a very good clay shale which will burn to a good grade of building brick and tile, and some of the shales are adapted to the manufacture of paving-brick. A test on this shale is given in the next section.

TESTS ON BRICK SHALES IN EASTERN PANHANDLE AREA.

Nineteen samples of shales and two of clays were taken from representative outcrops near railroad lines in Morgan, Berkeley, and Jefferson Counties, and sent to the U. S. Bureau of Standards laboratory at Pittsburgh, where they were carefully tested with the results given below. These tests show the great possibilities for clay industries in this eastern section of the State.

The methods used in making these tests are described as follows by this Bureau:

Each sample as received was ground in a Stevenson dry pan and screened through a ten-mesh sieve. A portion of the sample was tempered with water and wedged on a marble slab until it acquired stiff-mud consistency. Twenty-four briquettes, 2″ x 1⅛″ x ⅝″, were molded from each clay by pressing in the stiff-mud condition on a hand repress machine, the test pieces being numbered consecutively, A, B, C, etc. Test pieces Nos. 1, 2, 3, and 4 from each batch were weighed in the moist state and after drying, and the plasticity was then calculated in terms of the dry weight of the clay. Linear measurements were also made on test pieces Nos. 1, 2, 3, and 4, and the linear drying shrinkage determined in terms of the wet length of the briquettes.

Drying Treatment.—The series of briquettes were allowed to dry at room temperatures until they acquired leather-hard consistency, the final drying being in an electrically heated drying oven at 75° and 110° C.

Burning.—The test pieces were placed in a down-draft test kiln fired with natural gas in a manner such that trials from each shale could be drawn from the kiln at different temperature intervals. Two burns were made on the 21 samples. The kiln temperature was increased at the rate of 30° C. per hour after 800° C., the duration of burning being 48 hours for each set of trials.

Porosity Determinations.—The porosities of the briquettes burned to the different temperatures were determined by the use of the formula:

$$\frac{W - D}{W - S} \times 100 = \text{per cent. porosity,}$$

in which W = the weight of the briquette saturated with water, D = the dry weight of the briquette, and S = the suspended weight of the briquette. Before determining the wet weights, the pieces were boiled two hours in water in a vacuum. The data obtained from the porosity and shrinkage measurements and general observations as to the nature of the clays are given below. The temperature range of a material is obtained from the porosity data by considering a porosity of 6 per cent. to be that of ordinary commercial vitrification. A porosity between 6 and 12 per cent. may be taken as representing the commercial range of the average shale. If between these porosities the temperature difference is considerable, the material has a good range.

From a study of these tests the Bureau gives the following summary:

"From an examination of the data and observations, it will be noted that most of the shales are suitable for the manufacture of building brick, and that an appreciable number have properties which are favorable to the production of paving brick."

Tests on Morgan County Shales.

The Clinton Shales in Morgan County are buff in color, fine and flaky in texture, and break with smooth fracture. They outcrop in long narrow bands on both sides of Cacapon Mountain and they are also exposed by erosion on the summit of this mountain. A long area of good width is exposed along the Baltimore and Ohio Railroad east of Great Cacapon Station. A hundred-pound sample of this shale was taken on the mountain road on the west slope, a quarter mile south of the railroad. The results of the tests at the U. S. Bureau of Standards laboratory on this sample are given below under the heading of Great Cacapon.

On the east foot of Cacapon Mountain the Clinton again outcrops bending around the north end of the mountain and there uniting with the west belt to form a broad outcrop which extends north to Sir Johns Run and beyond. A sample of the shale was taken on the county road where it bends around the "Devils Nose", three-fourths mile south of Sir Johns Run Station, and the tests are given under the heading of Sir Johns Run. Both shales burn red in color and have fair plasticity and working properties, with satisfactory drying behavior.

The water of plasticity in percentage of dry weight in the Great Cacapon shale is 18.48; and in the Sir Johns Run, 22.36. The linear drying shrinkage in per cent. of dry length in the former is 1.85; and in the latter, 2.37. The linear burning shrinkage in terms of dry length is as follows:

°C.	Great Cacapon.	Sir Johns Run.
1000	0.05	1.58
1090	3.68	4.08
1180	6.88	5.70

The percentage of porosity at the different temperatures is given in the following table:

°C.	Great Cacapon.	Sir Johns Run
900	.....	33.00
950	....	31.50
1000	27.88	29.10
1030	27.55	27.10
1060	23.92	24.35
1090	18.37	22.52
1120	14.45	19.95
1150	10.04	17.46
1180	7.56	14.91
1210	5.70	13.86
1240	4.19	13.25
1270	.....	11.52

The Bureau makes the following remarks on the Great Cacapon shales:

A red burning shale having working and drying behavior suitable for the manufacture by the stiff mud process. The vitrification behavior is good and the material is a promising one for the manufacture of paving brick, etc."

The Sir Johns Run sample is, "a red burning shale of low plasticity, although it may be worked on an auger machine. The material is suitable for the manufacture of porous building brick. The shale is not promising for paving brick on account of the high temperatures necessary for low porosities."

Four samples of Hamilton (Devonian) Shales were selected from Morgan County for tests; one near fork of roads to Woodmont, a half mile south of Great Cacapon Station; one from the street excavation on the first road east of the Main Street in the town of Berkeley Springs; one from the south edge of the town of Cherry Run; one of the shale gravel due to the prolonged weathering of the shale at the east edge of this town. and just south of the Baltimore and Ohio Railroad.

The plasticity of the four shale samples was low except the shale gravel formed by weathering. All showed satisfactory drying behavior and all burned to a red color. The water of plasticity in per cent. of dry weight was in the Great Cacapon sample. 18.37; Berkeley Springs, 15.14; Cherry Run, 14.55; shale gravel, 18.56. The linear shrinkage in per cent. of dry length was, Great Cacapon, 2.25; Berkeley Springs, 1.44; Cherry Run, 1.64; shale gravel, 2.48.

The linear burning shrinkage in terms of dry length was:

°C.	Great Cacapon.	Berkeley Springs.	Cherry Run.	Shale Gravel.
950 ...	.....	0.45	0.15 (expansion)	.....
1000 ...	1.47	.....	.....	0.55
1060 ...	.....	3.18	2.38	.....
1090 ...	3.81	.....	.....	4.64
1150 ...	.....	1.97	2.38 (expansion)	.....
1180 ...	5.43	.....	.....	5.00
1240 ...	.....	.....	.....	3.56 (expansion)

The percentage of porosity at the different temperatures was,

°C.	Great Cacapon.	Berkeley Springs.	Cherry Run.	Shale Gravel.
900	29.68	27.10	25.20	.....
950	28.57	25.39	24.45	31.85
1000	26.30	21.38	21.52	31.10
1030	24.32	17.92	17.56	28.95
1060	20.81	15.10	13.81	25.38
1090	18.12	12.58	10.55	18.95
1120	13.95	9.45	7.30	14.55
1150	10.68	8.16	6.54	9.07
1180	8.22	8.40	Overburned	6.22
1210	5.47	.....	.....	2.98
1240	4.52	Overburned	.....	4.59
1270	3.57	.....	.....	Overburned

From a study of these tests on Hamilton Shales, the Bureau reached the following conclusions: The Great Cacapon material is "a red burning shale of somewhat low plasticity, although it may be worked on an auger machine. The vitrification behavior is excellent and the material is a very promising one for the manufacture of building and paving brick."

The Berkeley Springs sample is "a red burning shale of low plasticity, although it may be worked in an auger machine. The vitrification behavior is suitable for building brick. The material is not a promising one for paving brick on account of the tendency to overburn before attaining a low porosity."

The Cherry Run Shale is "a red burning shale of low plasticity and bonding power. Difficulties would be encountered in working on auger machine. The material is not promising for the manufacture of building and paving brick on account of the short vitrification and expansion in burning."

The weathered shale or shale-gravel at Cherry Run is "a red burning shale having good plasticity and working properties. The vitrification behavior appears favorable to the manufacture of building brick, although the range is somewhat short for paving brick."

A sample of the Chemung Shales (Devonian) was taken just south of Woodmont Station on the east side of a narrow ravine and in a recent, deep roadside cut. The tests show this yellow shale to be low in plasticity; water of plasticity in proportion to dry weight, 15.96 per cent.; linear drying shrinkage, 1.35 per cent.; and the shale burns to red color. The linear burning shrinkage in terms of dry length was:

°C.	Per cent.
1000	0.70
1090	2.06
1180	2.52
1240	2.76

The percentage of porosity at the different temperatures was:

°C.	Per cent.	°C.	Per cent.
900	27.70	1120	18.98
950	27.20	1150	17.75
1000	25.57	1180	16.41
1030	24.55	1210	13.95
1060	22.25	1240	11.92
1090	21.20	1270	9.30

The Bureau comments on these tests as follows. "A red burning shale of somewhat low plasticity. The material is suitable for building brick. In the manufacture of paving-brick, it would be necessary to burn this shale to a higher temperature than ordinarily is attained in paving-brick kilns in order to attain a low porosity."

Two samples of the bright-red Catskill Shales were tested. One sample was taken a half mile southwest of Woodmont Station; and the other was taken one mile east of Sleepy Creek Station on the county road to Cherry Run near fork to south, and about half mile south of the Baltimore and Ohio Railroad. The second locality is about 18 miles east of the first.

The water of plasticity required in the Woodmont sample is 17.70 per cent.; and at Sleepy Creek, 18.34 per cent. The linear drying shrinkage in the former is 1.85 per cent., and in the latter, 2.08 per cent. The linear burning shrinkage in per cent. of dry length was,

°C.	Woodmont.	Sleepy Creek.
1000	0.61	0.34
1090	2.54	4.88
1180	4.84	7.19
1240	4.84	.....

The percentage of porosity at the different temperatures was,

°C.	Woodmont.	Sleepy Creek.
900	28.10	.....
950	27.40	27.58
1000	26.10	26.45
1030	24.68	21.93
1060	22.64	18.60
1090	19.77	13.50
1120	17.51	7.89
1150	15.25	5.32
1180	11.28	4.49
1210	8.02	5.41
1240	6.61	Overburned
1270	Overburned	

The Bureau makes the following remarks on these two shales: The Woodmont sample is "a red burning shale of low plasticity, although it may be worked on an auger machine. The material is suitable for building brick manufacture. The vitrification range is not favorable for paving-brick, on account of the relatively high temperature at which a low porosity is attained."

In the Sleepy Creek sample, "the plasticity and working behavior of this shale is favorable to the manufacture by the stiff-mud process on an auger machine. The vitrification behavior is good and the material is a promising one for the manufacture of paving and building brick."

Tests on Berkeley County Shales.

The Hamilton Shales form a broad outcrop in the western and northwestern portions of Berkeley County. The Baltimore and Ohio Railroad cuts through these shales from Cherry Run to the North Mountain. A sample of this shale was taken near the west end of the deep railroad cut, one and a half miles north of North Mountain Station, and west of the contact with the Martinsburg Shale.

The tests show this shale to be somewhat low in plasticity, with water of plasticity percentage, 18.14. The linear drying shrinkage in per cent. of dry length was 1.67. The linear burning shrinkage in terms of dry length was:

°C.	Per cent.
950	0.40
1060	2.66
1150	4.43

The per cent. of porosity at the different temperatures was:

°C.	Per cent.	°C.	Per cent.
900	29.20	1120	9.24
950	28.45	1150	7.34
1000	25.75	1180	6.23
1030	21.08	1210	2.30
1060	16.54	1240	Overburned
1090	13.50		

The Bureau concludes from these tests that this sample is "a red burning shale of somewhat low plasticity, although it may be worked on a stiff-mud auger machine. The material is suitable for building-brick manufacture. The vitrification behavior appears favorable for paving-brick manufacture."

The most important group of shales in Berkeley County is the Martinsburg Shale, which forms a rather narrow belt along the east foot of the North Mountain, and a broad belt extending from the Potomac River southward across the County to the east of Martinsburg. This shale is crossed by both the Baltimore and Ohio and Cumberland Valley Railroads, and the numerous deep cuts on these roads show its extent and structure.

The only brick plant now in operation in the three counties is located on the North Mountain Shale belt, three-fourths mile north of North Mountain Station, and at the side of the Main Line of the Baltimore and Ohio Railroad. This shale and plant are described in detail in a preceding section of the present Chapter.

For the tests, a sample of this shale was taken from the large open pit east of the county road and near the plant. The second sample was taken from the new pit west of the road and reached by a tunnel driven under the road. The water of plasticity in per cent. of dry weight in the shale east of the road was 25.31; and west of the road, 27.77. The linear drying shrinkage in per cent. of dry length is 4.02, east of the road, and 4.17, west of the road. The per cent. of linear burning shrinkage in terms of dry length was,

°C.	East of Road.	West of Road.
1000	0.83	1.40
1090	6.51	5.82
1180	8.04	8.42
1240	4.57	5.34

The per cent. of porosity at the different temperatures was:

°C.	East of Road.	West of Road.
900	36.92	36.39
950	36.60	36.10
1000	35.35	35.22
1030	32.20	31.45
1060	27.19	27.95
1090	19.15	19.08
1120	10.86	12.78
1150	5.16	8.17
1180	5.13	8.34
1210	4.96	5.79
1240	8.94	6.33
1270	Overburned	Overburned

The Bureau concludes from these tests that both samples represent, "a red burning shale having good working and drying properties. The vitrification appears favorable to the manufacture of paving-brick. Any excessive lamination of this shale in manufacture could probably be avoided by changes in grinding methods and die construction."

In the northern edge of the city of Martinsburg is the Buxton Brick Works, which for nearly twenty years has been supplying the local trade, but the plant has been idle for the past few years. A sample of the shale was taken from the large open pits in front of the plant, and another was taken of the prismatic weathered shale bank close to the plant.

The water of plasticity in per cent. of dry weight of the shale from the open pits was 23.86; and from the bank at the plant, 18.07. The linear drying shrinkage in per cent. of dry length of the former was 4.01; and of the latter, 1.98. The linear burning shrinkage in terms of dry length was,

C.	Open Pit.	Bank at Plant.
950	0.72	0.41
1060	6.75	4.78
1150	7.60	3.99
1210	0.72	.....

The per cent. of porosity at the different temperatures was:

C.	Open Pit.	Bank at Plant.
900	34.12	28.79
950	32.50	27.60
1000	27.05	21.90
1030	19.95	17.14
1060	13.68	12.49
1090	8.35	9.06
1120	3.79	6.38
1150	3.19	5.54
1180	2.53	7.60
1210	8.10	Overburned.

The Bureau reached the following conclusions from these tests. The shale from the open pits and used at the plant is, "A red burning shale having good plasticity and working behavior. The vitrification behavior is excellent and the material is a promising one for the manufacture of building or paving brick."

The shale bank close to the plant is fairly solid outcrop, much less weathered than in the open pits and its texture is quite different. It is, "a red burning shale of somewhat low plasticity, although it may be worked on a stiff-mud auger machine. The material is suitable for building brick. The vitrification range is somewhat short for a paving-brick material."

Another sample of the Martinsburg Shale was taken on the lands of the Berkeley town-site company, four miles north of Martinsburg, east of the Cumberland Valley Railroad.

A sample of this shale was also taken on the lands of the National Limestone Company, two miles southeast of Martinsburg, near Evans Run, and east of the Sulphur Springs county road.

The water of plasticity in per cent. of dry weight in the Berkeley sample was 28.70; and in the National sample, 20.14. The linear drying shrinkage in per cent. of dry length in the former was 4.40; and in the latter, 1.25. The linear burning shrinkage in terms of dry length was,

°C.	Berkeley.	National.
950	0.98	....
1000	.....	1.68
1060	8.06	....
1090	.....	5.62
1150	10.10	....
1180	.....	5.33
1210	5.23	....
1240	.....	1.43 (Expansion)

The per cent. of porosity at the different temperatures was:

°C.	Berkeley.	National.
900	33.90	.....
950	33.28	33.50
1000	27.30	31.68
1030	20.85	27.25
1060	12.34	23.88
1090	6.49	15.25
1120	3.13	9.93
1150	2.63	7.08
1180	1.79	6.48
1210	3.88	.....
1240	Overburned	5.63

The Bureau concludes from the tests on the Berkeley sample that it is, "a red burning shale of good plasticity and working properties. The material is suitable for the manufacture of building brick. The extremely low porosity attained and the high drying shrinkage are unfavorable to the manufacture of paving brick on account of the brittle structure resulting."

The National sample is, "a red burning shale of somewhat low plasticity, although workable by the stiff-mud process on an auger machine. The vitrification behavior appears favorable to the manufacture of building brick, paving brick, etc."

Two samples of the Martinsburg Shale were taken on the **Houck farm** just north of the Main Line of the Baltimore and Ohio Railroad, and west of Opequon Creek, or about two miles east of Martinsburg. One sample was of the surface weathered, smooth, blocky, yellow shale, and the other was obtained from a pit sunk some distance below the surface.

The water of plasticity in per cent. of dry weight in the pit sample was 16.69; and in the surface shale, 25.54. The linear drying shrinkage in per cent. of dry length in the former was 2.26; and in the latter, 2.28. The per cent. of linear burning shrinkage in terms of dry length was,

°C.	Pit.	Surface Shale.
950	1.93	0.15
1060	5.09	5.52
1150	4.72	8.81

The per cent. of porosity at the different temperatures was:

°C.	Pit.	Surface Shale.
900	28.41	34.73
950	25.75	33.75
1000	21.12	29.10
1030	15.75	24.60
1060	8.60	17.76
1090	6.27	12.71
1120	4.45	6.76
1150	3.53	5.33
1180	4.54	3.89
1210	3.23	.....
1240	2.89	2.13
1270	Overburned	1.79

The Bureau concludes from these tests on both samples that this outcrop on surface and in deeper excavation is, "a red burning shale having good working and drying behavior. The material has an excellent vitrification behavior, and is very promising for the manufacture of building brick and pavers."

Near Tablers Station on the Cumberland Valley Railroad, four miles south of Martinsburg, is a large deposit of pottery clay on the **Tabler farm** that should have a value for stoneware manufacture. Similar clays are found at a number of places in the Martinsburg District, and some of the clays were used for this ware many years ago. In order to determine the real value of these clays, they should be tested at some pottery plant.

A sample of the Tabler clay was tested, and its behavior under fire noted. While the results are not as favorable as hoped for, the sample was from the surface, and deeper pits would doubtless show an improvement in quality. This is a very plastic clay with per cent. of water of plasticy, 34.64. The sample had a high drying shrinkage of 11.31 per cent. which caused cracking. The linear burning shrinkage in per cent. of dry length was:

°C.	Per cent.
1000	5.75
1090	7.10
1180	6.52

The clay burns to a reddish-buff color, the iron percentage being only about one-half that in the Martinsburg Shale. The per cent. of porosity at the different temperatures was:

°C.	Per cent.	°C.	Per cent.
900	12.75	1120	1.58
950	9.12	1150	1.91
1000	2.57	1180	1.86
1030	2.01	1210	6.53
1060	1.76	1240	Overburned
1090	2.20		

The Bureau concludes this is, "an excessively plastic clay, having a high drying shrinkage which causes cracking during drying. The material is not suitable for building or paving brick. The material vitrifies to a very dense structure and might be used in the manufacture of vitrified ware of the stoneware class, although the burned color is inferior to that of the stoneware clays, and difficulties from lamination and drying cracks would be encountered."

Tests on Jefferson County Clays.

The Martinsburg Shales outcrop in the southwestern portion of Jefferson County, and are there probably similar to those in Berkeley, but they are not accessible to the railroad. Over the limestones of the county are heavy deposits of residual red clays that have been used in past years for brick manufacture at small plants at Shepherdstown and Charlestown. These plants have been abandoned and dismantled, except one at Charlestown,—the Valley Brick Company, at the north edge of town,—which is fully equipped with modern machinery and made a common building brick for local use. The plant has been idle for two years, but plans are under way to renew the operation.

Two samples of the red clay used at this plant were taken from two places in the large pit which is worked down to the limestone (Elbrook), and they were numbered 1 and 2. The clay is very plastic and the water of plasticity in per cent. of dry weight in No. 1 was 31.39; and in No. 2, 33.75. The linear drying shrinkage in per cent. of dry length in the former was 7.84; and in the latter, 8.97. The high shrinkage involves difficulty in cracking in the process of manufacture. The linear drying shrinkage in per cent. of dry length was:

°C.	No. 1.	No. 2.
950	2.50	1.57
1060	12.25	8.54
1150	8.58	0.00

The per cent. of porosity at the different temperatures was:

°C.	No. 1.	No. 2.
900	34.80	33.85
950	33.42	32.42
1000	16.82	25.65
1030	7.07	16.86
1060	3.47	9.65
1090	1.91	7.09
1120	1.94	2.49
1150	1.25	1.06
1180	7.85	6.98
1210	Overburned	Overburned

The Bureau concludes from these tests that this is, "a red burning clay having excessive plasticity and drying shrinkage and a short vitrification range. The properties are not favorable to the manufacture of building brick of high grade. In No. 1, a lower porosity is attained at a lower temperature."

ROAD MATERIALS.

In the Eastern Panhandle Area of West Virginia, there is an abundant supply of good rock for the building and improvement of the county roads. This rock is well distributed over the area, so that quarries can be opened convenient to the roads over the greater portion of the counties thereby lowering the cost. Nature has certainly done her part in the supply and convenience of good-roads materials in this section, but this supply has not been used to the extent necessary over the entire area. There appears to be a progression eastward in the growth and development of good roads. The Morgan County roads, while being improved each year, are far from what they should be. Berkeley County has better roads, while Jefferson is the best good-roads county in the State.

In Morgan County there are available for roads the hard sandstones of the Medina on and near Cacapon Mountain. The hard Keefer quartzite sandstone in the Sir Johns Run Valley, and the Carboniferous hard sandstones of Purslane-Sideling Hill and Meadow Branch Mountains could be used to advantage in those areas. In the Devonian Shales are hard greenish sandstones and the Parkhead brown sandstones and conglomerates should prove serviceable. The Oriskany and the Catskill Sandstones are too crumbly and would soon form sand on roads.

The sandstones are usually very hard, so somewhat expensive to crush, but in a number of places in Morgan County are good beds of limestone that are most valuable road material. These limestones have been used in this county to a very limited extent. One limestone ballast plant is in operation near Berkeley Springs, and its sales only permit it to run on a small scale a portion of the time. This plant should be operated eight to nine months a year at its fullest capacity for use entirely on county roads of this portion of the county. The investment would be most profitable to the people of Morgan County whose roads should equal those of Maryland.

This belt of Helderburg Limestone, quarried at this one place at the north and for a small lime plant in the southern part of the county, follows along the west upper slope of Warm Spring Ridge the length of the county. It could be opened at various places along the Ridge, and there should be a model macadamized road the full length of the Warm Spring Valley, with branches east to the Sleepy Creek Valleys. In this large southern area of Morgan County are rich farming and fruit lands with nearest railroad shipment point at Berkeley Springs, 10 to 18 miles distant, over roads that in bad weather are at many points impassable for loads. A good rock roadway through this valley would result in production of greater crops in this area, and would place more land under cultivation. The cost of such a road would soon be repaid by increased production of the area and increased sales of products.

Most of the roads in this area are made of the Devonian Shales which make beautiful and solid dry weather highways. They require frequent repairs or they become full of ruts and holes, and in wet weather are very muddy. If kept in repair they would probably replace many of the advantages of the rock road. However, in this county, as in most other counties, when a shale road is completed, future years' work is demanded in other sections and the new shale road is left to shift for itself for years until it loses all resemblance to a good road. Shale roads require frequent attention and repairs; and when repairs are needed, they are not made. The rock road, made on scientific road principles, is costly in the first instance, but its upkeep is low.

The crushing of rock and placing it in heaps here and there along an old dirt road, with no attention paid to drainage or outline of the road, is a very common method in this State in road improvements. This method is a waste of rock and money, and seldom results in much permanent improvement in roads. The attempt to make a wagon-load of stone

PLATE XXXVI.—View showing the Catskill Sandstone Ledges in Cut of Baltimore and Ohio Railroad West of Doe Gully.

cover as long a stretch of road as possible with a thin layer is another waste.

Another belt of Helderberg Limestone outcrops along the east slope of Tonoloway Ridge and would be accessible at a number of places near roads which to-day are far from good roads. Below this good road limestone is the Bossardville Limestone in the same areas as the Helderberg. This limestone breaks flaggy and while inferior to the more solid limestone above, could be used to advantage near its outcrop. In places it is a fairly hard limestone, and with care in selection should prove valuable. In a later section, some tests are given on these Morgan County road materials which will show their relative value.

Berkeley County is richly endowed with road materials. Along its mountains and ridges are the hard sandstones which might find a local use, and would be especially valuable as a substructure or foundation for limestone surfaced roads. In the Back Creek Valley in Ferrel and Wilson Ridges are outcrops of the Helderberg Limestone, also the Bossardville. Here are outcrops of calcareous sandstone of the Oriskany. These limestones show in good, solid outcrops, convenient to roads, and to-day find practically no use on the roads.

The Back Creek Valley is one of the richest agricultural and orchard sections in the county, separated by mountains from the railroad points to east and west except at the north. The natural outlet for these products is northward to Cherry Run Station or by Hedgesville Gap to North Mountain Station. Good stone macadamized roads should lead through this rich valley to these points, and the stone is convenient for this purpose; yet no such road exists and shale roads are the rule. These shale roads are for the most part kept in a fair degree of repair and they are far better than some roads in other parts of the county. With the rapid development of the great orchard industry of this valley and the lack of a railroad line through the valley, it would be a wise and most profitable investment to construct a main road north and south by Glengary, Shanghai, Jones Springs, Tomahawk, to Hedgesville and Cherry Run, built from this Helderberg Limestone in these ridges. It would be an expensive project in its construction, but its low cost of repairs through the coming years would make the cost in the long run low.

East of North Mountain, Berkeley County, is a great limestone area with the various limestones of the Shenandoah Limestone Group outcropping in nearly all parts and near most of the county roads. For many years the only good roads in the county were the toll pikes, and county roads proper were typical illustrations of poor roads, far from being a credit to such a rich county. In the past few years great interest has been taken in the subject of better roads for the county. The County Court has been very active in this work. The result has been a remarkable growth of good roads. They now have the road from the Winchester Pike to Arden, the Shepherdstown road from that place to the Baltimore and Ohio Railroad at Van Clevesville, two roads that equal or surpass the toll pikes. Work is also being done here and there on other roads in the county. There is thus a marked improvement in Berkeley County roads, with plenty of room for further work. This growth of improved roads in the county is held back by lack of sufficient funds, and the County should issue good-roads bonds for larger work.

Berkeley County is exceptionally favored in its supply of road materials, over other counties to the west. With portable crushers, quarries could be opened convenient to the roads over the county so that the cost of transportation would be very low. All of these limestones can be used, though some are more suitable to good roads than others. The hard, more siliceous limestones of the series would be better than the friable and brittle high-grade rock of the Martinsburg quarries.

The broad belts of Conococheague and Beekmantown Limestones from Martinsburg west which extend the full length of the county are valuable road materials, and they have been used at a number of places with good results. The Chambersburg Limestones over the high-grade limestone, while cobbly on surface weathered outcrops, are in solid, hard ledges below the surface as may be seen in the small roadside quarries north of Falling Waters, and in the small quarry southwest of Van Clevesville beyond the Van Metre School-house.

On a number of roads in Berkeley County in the Elbrook Formation to the south of Hedgesville, and near Nollville, the cherts are crushed and make a durable road though the cementing property is low so that the fragments do not bind together in a firm bed. If mixed with limestone, there would probably result a much better road. In the Back Creek Valley, some portions of the roads near Ferrel Ridge are made from the hard cherts or flints found in the Helderberg and Oriskany Formations. These cherts are available over the large area of the outcrops especially of the Elbrook and Beekmantown Formations. The fields on these outcrops are dotted with large piles of these cherts. A chert belt extends southwest from the river crossing the roads east of Prospect Hill, Spring Mills, etc., on the south. These cherts have been used on a number of the roads on this belt and have made fairly durable roads. The mixture of limestone with the cherts could be used in this section to advantage and the limestone outcrops with the cherts.

In the shale area of the county east from Martinsburg, shale roads are the rule, but they are not usually kept in very good repair and some of them are almost impassable in bad weather. Some of these roads leading from Martinsburg to the Opequon are model shale roads and have been kept in very good condition. The Schoppert Ford road from North Martinsburg east to the Opequon has been graded with deep shale cuts and represents a very expensive road and is one of the best shale roads in the State. Good limestone is found just across the Opequon and if this road was now macadamized with this stone, it would be a great improvement.

The shale road from Martinsburg southeast and leading to Shepherdstown illustrates the difficulty of keeping shale roads in repair. This road has heavy travel and wears into a series of rolls and hollows, with holes here and there. These are filled with shale and in a short time the trouble is repeated. The only permanent remedy is a rock road through this section to the Opequon. On this same road on the shale hill west of Van Clevesville, bad weather renders this portion of the road very difficult to travel or haul heavy loads across. In these shale areas limestone being absent, the cost of rock would be greater, but on the Van Clevesville portion of the road, good limestone outcrops at the top of the ridge and again at the bottom of the hill near Van Clevesville. Shale roads should be carefully drained, a condition very often overlooked.

Jefferson County is practically covered with limestone and for a long period of years its people have taken great interest in good roads. Very few roads in the county are dirt roads and nearly all have a covering of rock. Turnpikes lead in all directions which are kept in good repair and free from toll charges. The main roads are all made of rock and the few dirt roads are short, leading across from one pike to another in sections not thickly settled.

In this county are the broad outcrops of Conococheague, Beekmantown, and Waynesboro Limestones, in addition to the cherts and flaggy limestones of the Elbrook. There are many small roadside quarries in these limestones opened for use on the county roads. In the Waynesboro are the hard, blue, siliceous limestones and also white marble ledges, all used on roads. Examples of main road pikes that are kept in good repair are the Smithfield and Shepherdstown road, Halltown and Shepherdstown Pike, Flowing Springs road, Harpers Ferry, Charlestown, and Middleway Pike, the Charlestown and Berryville Pikes, Meyerstown, Rippon, and Summit Point Road, Kabletown Pike. These are well-graded and drained roads that receive a large amount of travel and resemble closely the toll roads in other sections. These are main roads of travel across the county, while many of the branch roads are in equally good condition. Across the Shenandoah are the hard sandstones of the Weverton which are used on these mountain roads at a number of places with success.

Mr. A. D. Williams, Road Engineer of this State, in his Bulletin No. 5 (page 41), gives tables of cost of construction of macadam roads, a portion of which is here quoted:

10 Feet Wide.

Thickness.	Cubic Yards Stone per Mile.	Cost stone per mile at 50c per yard.	Cost stone per mile at 75c per Yard.	Cost per Mile loading stone. 15c per Yard.	Cost Haul 32c per Yard per Mile.	Cost per Mile Spreading and rolling. 12c per Yard.	Total cost per Mile, stone 50c.
2	423.7	$212	$ 318	$ 64	$136	$ 51	$ 463
4	847.4	424	636	127	271	102	924
6	1271.1	636	954	191	407	152	1386
8	1694.8	848	1272	254	542	203	1847

14 Feet Wide.

Thickness.	Cubic Yards Stone per Mile.	Cost stone per mile at 50c per yard.	Cost stone per mile at 75c per Yard.	Cost per Mile loading stone. 15c per Yard.	Cost Haul 32c per Yard per Mile.	Cost per Mile Spreading and rolling. 12c per Yard.	Total cost per Mile, stone 50c.
2	593.2	$297	$ 445	$ 89	$190	$ 71	$ 647
4	1186.4	593	888	178	380	142	1293
6	1779.6	890	1334	267	570	214	1941
8	2372.8	1186	1779	356	760	285	2587

According to the records of the State Road Bureau, furnished by the Chief Engineer, A. D. Williams, these three eastern counties have the following road mileage.

	Total Miles.	Macadamized.
Morgan	325	3
Berkeley	456	96½
Jefferson	340	280

TESTING OF ROAD MATERIALS.

The subject of better roads is now attracting wide attention all over the country and many States have an organized State Bureau of Public Roads with trained engineers in charge. States and counties are making appropriations on large scale to build good roads, and all counties now have road supervisors or road engineers in charge of the road building and repairs in the counties. In West Virginia there is established at Morgantown a State Road Bureau with Mr. A. D. Williams in charge, which is stimulating interest in better roads over the State. A series of bulletins is issued giving directions for the proper construction of these roads and other helpful data, which are distributed free over the State. Much good has been accomplished by this Bureau, and its influence for good will greatly increase when it has educated the people to the need and value of improved road conditions.

It has been shown that in the three counties described in this Report there is a vast supply of road materials near at hand. Not all rocks are adapted to the best service on roads. Some of these rocks are better than others, and it becomes important to select the best materials available. It is possible by certain laboratory tests to determine whether a certain rock is suitable tor road consruction, and which of a number of rocks is best adapted to this use. These tests are therefore very important and should be made, if possible, on the materials to be used. The Government has an organization under the Department of Agriculture known as the Office of Public Roads, established in December, 1900, which is in charge of a corps of experts with Mr. Logan Waller Page, Director. This department is equipped with modern testing machinery, whereby the qualities of various road materials can be determined. This department has very kindly cooperated with the West Virginia Geological Survey in testing samples of road materials from this eastern Panhandle area and the results are given later in this Chapter.

Bulletin No. 44 of the U. S. Office of Public Roads describes the methods and results of physical tests on rock for road building and the following description of these tests is taken from this bulletin.

The authors of this bulletin (A. T. Goldbeck and F. H. Jackson) call attention to the fact that two sets of agencies work the destruction of roads, as a macadam road is composed of individual stones bound together by smaller particles and rock powder. The first set of destructive agencies is mechanical. The impact of horses' feet tends to loosen the binding material and crowd the rocks apart, and at same time the abrasion grinds away the surfaces of the stone forming dust which may be carried away by the wind or washed away by rain. The part which does remain will form new binding or cementing material. If too much is present the road will be dusty and muddy, and if not enough to properly cement the rocks together, the road will disintegrate by raveling out.

They call attention to the automobile traffic exerting a severe shearing action on the road which loosens the individual stones and does not supply by abrasion the fine material to overcome the loss in the cloud of dust raised by them. Plain macadam road without any surface oil or cement binder is thus seriously injured and rapidly destroyed by such traffic.

The other class of injurious agencies is physical. The freezing and thawing action loosens the materials in the body of the road and such loosened materials are carried away by wind and rain. The action is more destructive on roads that are poorly drained. While the rocks used may have low absorption, the road-bed aggregate has a large absorptive power, the interspaces holding water. The authors of this bulletin call special attention to the fact that the mechanical wear of traffic is far more severe and destructive than that of freezing or thawing.

They state that a road building rock must have three very essential characteristics. 1. **Hardness**, or "its ability to resist the abrasive action of traffic in causing displacement of the surface particles by friction"; 2. **Toughness**, or "its ability to resist rupture due to the impact of traffic"; 3. **Cementing or Binding Power**, which "determines how firmly the individual stones will be cemented together by the rock powder formed through the action of traffic."

In order to determine the value of road materials, the following tests are made: hardness, toughness, resistance to wear or abrasion, cementing value, specific gravity, and absorption.

Hardness Test.—The hardness test is made on rock cores, 25 millimeters in diameter on the Dorry machine. The cores are held endwise, perpendicularly against a revolving steel disk, under a pressure of 1250 grams, while standard quartz sand (30- to 40-mesh) is fed on the disk for abrasion. At the end of 1000 revolutions, the loss in weight is determined, and the test repeated with the core reversed. The average loss in weight of the two runs is used in the determination of the hardness of the specimen by the following formula where **W** is the loss in grams per 1,000 revolutions:

$$\text{Hardness} = 20 - \tfrac{1}{3} W.$$

Toughness Test.—The toughness test is made on rock cylinders cut out of the specimen rock, 25 millimeters in diameter and of equal height. These cylinders are tested in a Page impact machine, under the impact of a two-kilogram (4.4 pounds) hammer falling on a plunger having a spherical end two centimeters in diameter. The first blow is delivered from a height of one centimeter, the second from a height of two centimeters, and so on until the test piece begins to crumble down. The number of blows required to cause the break in test piece represents the toughness.

Abrasion Test.—The abrasion test in the Deval machine tests both hardness and toughness and gives clue to the resistance to wear of the rock. The Deval machine is an iron cylinder 8 inches in diameter, 13½ inches deep, mounted diagonally (30°) on a rotating axis. The rock is broken in uniform-sized pieces so that about 50 pieces make a test sample weighing approximately 5 kilograms (11 pounds) and thoroughly dried and weighed. They are placed in the cylinder which is firmly closed and rotated for 10,000 revolutions at the rate of 30 to 33 per minute. The percentage of material worn off which will pass through a 1/16-inch sieve is used in determining the amount of wear which is given in per cent. of the 5 kilograms used and is known as per cent. of wear.

The French engineers who established this test adopted a **coefficient of wear** to indicate the resistance to wear of a stone. They found that very few rocks in these tests form less dust than 20 grams to each kilogram of rock, and they adopted the number 20 as the coefficient of the best rocks. The coefficient of other rocks is obtained by multiplying this number by 20 divided by the amount of dust formed per kilogram of rock, W being the weight in grams of the dust or particles under 1/16 inch,

$$\text{Coefficient of Wear} = 20 \times \frac{20}{W}$$

The French Coefficient multiplied by the per cent. of wear equals 40.

Cementation Test.—In this test one-half kilogram of the finely crushed rock sample is placed in a ball mill with sufficient water to produce a stiff dough after grinding. The mill is given 5,000 revolutions at the rate of 2,000 per hour, after which the dough is taken out and molded in a steel die under a pressure of 132 kilograms for not to exceed 30 seconds. Five briquettes are made and dried for 20 hours in air, then 4 hours at 200° F. They are then tested in a Page impact machine under a one kilogram (2.2 pounds) hammer which drops one centimeter. The reaction of the briquette after each blow of the hammer is recorded automatically by a lever with brass point on a sheet of prepared paper. When no further reaction is recorded, so that the resilience of the briquettes is destroyed, the test is complete. The number of blows required to reach this result is taken to be the cementing value of the material.

The **Specific Gravity Test** is a clue to the density of the rock, and the weight per cubic foot of the solid unbroken rock is obtained by multiplying the specific gravity by the weight of a cubic foot of water, 62.37 pounds.

This sample of stone used for specific gravity test is immersed in water for four days, and the absorption is expressed in pounds per cubic foot.

In the interpretation of the results of tests on rock samples and in the comparison of their value as road material, the bulletin quoted above gives the following values in the different tests:

Hardness:
Coefficient above 17.........hard.
from 14 to 17....medium.
below 14.........soft.

Toughness:
above 19.........high.
from 13 to 19....medium.
below 13.........low.

Resistance to Wear:
French Coefficient above 20.........very high.
from 14 to 20....high.
from 8 to 13.....medium.
below 8..........low.

Cementing Value:
above 100........excellent.
from 76 to 100...very good.
from 26 to 75....good.
from 16 to 25....fair.
below 10 ......low.

This bulletin also gives a table of limiting values in the above tests for different kinds of traffic:

Kind of Traffic.	Results of Tests.			
	Per cent. of wear.	Hardness.	Toughness.	Cementing Value.
Heavy	2.5 or less	18 or over	19 or over	over 25
Medium	2.5 to 5	14 to 18	14 to 19	over 25
Light	5 to 8	10 to 14	8 to 14	over 25

For purposes of comparison the following maximum and minimum results of all tests made on limestone, dolomite, marble, sandstone, chert, shale, and granite, in the laboratory of the U. S. Office of Public Roads up to January, 1912, are given:

No. Samples Tested	Kind of Rock.	Specific Gravity.			Weight lbs. per cubic foot.			Water absorbed lbs. per cu. ft.	
		Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.
718	Limestone	2.85	2.00	2.66	178	125	166	13.00	0.02
183	Dolomite...	3.00	2.30	2.73	181	143	170	9.40	0.07
37	Marble....	2.85	2.65	2.76	178	165	172	2.19	0.10
340	Sandstone..	3.25	2.00	2.61	203	125	163	11.00	0.02
52	Chert......	3.00	2.00	2.55	184	125	159	11.10	0.25
9	Shale......	2.70	2.50	2.65	168	156	165	4.84	0.50
219	Granite....	3.00	2.00	2.66	187	125	166	2.77	0.04

No. Samples Tested.	Kind of Rock.	Per cent. of wear.		French Coefficient of wear.		Hardness.		Toughness.		Cementing Value.	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
718	Limestone ...	34.2	1.8	21.7	1.2	19.1	0.0	25	2	500	9
183	Dolomite	18.6	1.2	33.3	2.2	18.8	1.8	27	3	179	9
37	Marble	14.0	2.3	17.5	2.8	17.3	7.1	23	3	85	10
340	Sandstone ...	41.7	1.0	40.8	1.0	19.5	0.0	60	2	500+	1
52	Chert	29.2	2.7	14.9	1.4	19.7	12.7	26	5	500+	2
9	Shale	16.2	3.2	12.6	2.5	17.7	13.9	12	3	367	28
219	Granite	24.6	1.1	37.0	1.6	19.6	13.6	33	2	255	2

TESTS ON MORGAN COUNTY ROAD MATERIALS.

The Bossardville (Tonoloway) Limestone from east slope of Tonoloway Ridge south of Great Cacapon Station was tested at the laboratory of the Office of Public Roads at Washington with the following results:

Weight per cubic foot	172	pounds.
Pounds of water absorbed per cubic foot	0.91	
Per cent. of wear	3.2	
French coefficient of wear	12.3	
Hardness	14.8	
Toughness	19.0	
Cementing value	71	

Tests made on the Helderberg Limestone near Berkeley Springs were as follows:

Weight per cubic foot	168	pounds.
Pounds of water absorbed per cubic foot	0.45	
Per cent. of wear	5.1	
French coefficient of wear	7.9	
Hardness	12.2	
Toughness	6	
Cementing value	42	

In the present work in these counties, samples were taken for tests from the Bossardville Limestone at a small lime quarry on the **Samuel Barnhardt farm,** two miles south of Berkeley Springs, on the western slope of the ridge. The slabby character of this formation made it impossible to secure a block of sufficient thickness to make the tests on Hardness and Toughness. The other tests made for the Survey by the Office of Public Roads at Washington are as follows:

Specific gravity	2.70	
Weight per cubic foot	168	pounds.
Pounds of water absorbed per cubic foot	0.36	
Per cent. of wear	6.5	
French coefficient of wear	6.2	
Cementing value	62	(good).

The report concludes this rock is only suitable for use on water-bound macadam roads subjected to light traffic.

Samples of the Helderberg Limestone were taken from the quarry of the **Forest Hill Lime Works,** a mile south of Berkeley Springs on the west slope of the Warm Spring Ridge. This quarry is equipped with a small crushing plant and supplies stone to the town. The stone has been used on the hill road back of the town. The tests, as made at Washington by the Office of Public Roads, are:

Specific gravity	2.70	
Weight per cubic foot	168	pounds.
Pounds of water absorbed per cubic foot	0.51	
Per cent. of wear	7.1	
French coefficient of wear	5.6	
Hardness	15.83	
Toughness	4	
Cementing value	71	(good).

The report states this rock is only suitable for roads with light traffic.

When these Bossardville Limestones are compared with the table of interpretation of values in a preceding paragraph, the hardness and toughness are medium. The resistance to wear in the Tonoloway Ridge sample is medium, and low in the other one. The cementing value is good in both samples. The table of limiting values shows the Tonoloway Ridge limestone to be adapted to medium traffic and the Warm Spring Ridge Bossardville Limestone only adapted to light traffic.

The two samples of Helderberg vary somewhat in results and were doubtless taken from different ledges. The sample taken in the present work was from a new quarry but recently opened. This sample shows medium hardness, low toughness, low resistance to wear with good cementing value, and, by the table, both samples are only suitable for light traffic, and would be suitable for these country roads.

Samples of the hard quartzose sandstones were taken. One sample of the hard, white Medina Sandstone was taken from the lower quarry of the Great Cacapon Silica Sand Company, near the mountain road. This is a very hard rock which has been exposed to the weather for several years in the open quarry. It was tested at the Washington laboratory of the Public Roads Bureau with the following results:

Specific gravity	2.60	
Weight per cubic foot	162	pounds.
Pounds of water absorbed per cubic foot	1.69	
Per cent. of wear	8.0	
French coefficient of wear	5.0	
Hardness	18.3	(high).
Toughness	8	(low).
Cementing value	23	(fair).

As a result of these tests the Bureau states the rock is only suitable for use in the foundation course of macadam roads.

The laboratory of the Office of Public Roads made a mineral examination of this Medina Sandstone and found as accessory minerals, orthoclase and zircon, with limonite or hydrated oxide of iron as a secondary mineral. They describe the sandstone as a "fine grained, light yellowish gray, highly indurated sandstone, composed essentially of angular quartz grains, firmly cemented together by silica and iron oxide."

At the base of the Niagara (McKenzie) Formation is a very hard quartzose sandstone that resembles somewhat in physical structure the preceding Medina White Sandstone. It outcrops in narrow belts near Great Cacapon Station, thence southward, and a long narrow belt outcrops east along Sir Johns Run and south across the county. It is very resistant to action of weathering and forms low ridges or solid rock cliffs.

This Keefer Sandstone was sampled on the road from Berkeley Springs to Great Cacapon a quarter mile to the west of the bridge over Sir Johns Run, or a mile west of Berkeley Springs (9561). It was again sampled further north on an eastern lens of this sandstone which crosses the road to Sir Johns Run and a quarter mile east of the run, and a mile and a quarter north of the Great Cacapon road, sample No. 9559.

	No. 9561		No. 9559.		No. 9564.	
Specific gravity.........	2.60		2.65		2.70	
Weight per cubic foot.	162	pounds	165	pounds	168	pounds
Pounds of water absorbed per cu. ft..	0.94		0.61		0.99	
Per cent. of wear......	5.1		3.00		4.00	
French coefficient of wear	7.8	(low)	13.3	(med.)	10.0	(med.)
Hardness	19.0	(hard)	18.83	(hard)	16.33	(med.)
Toughness	10	(low)	12	(low)	11	(low)
Cementing value.......	18	(fair)	13	(fair)	26	(good)

The Office of Public Roads states that these sandstones are "suitable for use as foundation course in water-bound macadam constructions, as foundation and wearing course in bituminous macadam roads subjected to moderate traffic, and as concrete aggregate."

They found in these sandstones as accessory minerals, orthoclase feldspar, tourmaline, and zircon, with limonite and hematite iron oxides as secondary minerals, the rock being composed essentially of angular quartz grains cemented together by silica and iron oxide.

Sample No. 9564 is of a ferruginous sandstone, deep reddish-brown color from the Bloomsburg Red Sandstone member at the base of the Rondout Waterlime (Wills Creek Shales). .It is from the roadside cliff outcrop on the Berkeley Springs-Great Cacapon road a quarter mile east of the bridge over Sir Johns Run. This belt extends north to the river and southwest across the county. It is composed of red shales, and solid sandstone ledges, and it is according to the tests suitable for foundation courses in macadam roads. According to the Government report, it is a fine-grained sandstone composed essentially of angular quartz grains cemented together by iron oxide, with tourmaline as accessory mineral, and hematite iron oxide as secondary mineral.

The above tests on Morgan County road material show that the hard quartzose sandstones are not adapted to use on macadam roads except for the foundation courses. Sandstones seldom make satisfactory roads when used on the surface. If very hard, the rocks do not cement together; and if softer, they grind down to a loose sand. If used in the foundation courses with limestone surfaces, they afford good drainage and a very solid road-bed.

The flaggy limestones of the Bossardville make only a fair road, but possibly in quarries opened to greater depth, a more solid limestone might be found. All openings are shallow and represent surface more or less weathered outcrops. The Helderberg Limestones are adapted to use on these country roads and should make a very satisfactory road material, and there is sufficient quantity to justify road quarry openings.

TESTS ON BERKELEY COUNTY ROAD MATERIALS.

The Office of Public Roads at Washington has made a number of tests on stone for use on roads, from Berkeley

County. Four miles north of Martinsburg are located the quarries of the Security Cement and Lime Company. The following tests were made on the high-grade limestone of the Stones River Formation at these quarries:

Specific gravity	2.70	2.70
Weight per cubic foot	168 pounds	168 pounds
Pounds of water absorbed per cubic foot	0.45	0.21
Per cent. of wear	5.1	4.6
French coefficient of wear	7.9	8.6
Hardness	12.2	16.0
Toughness	6	7
Cementing value	42	46

The overlying Chambersburg Limestone at these quarries was also tested with the following results:

Specific gravity	2.70	2.85
Weight per cubic foot (pounds)	168	178
Pounds of water absorbed per cubic foot	0.345	0.17
Per cent. of wear	4.1	2.8
French coefficient of wear	9.8	14.3
Hardness	15.7	17.2
Toughness	3	17
Cementing value	Good.	Good.

"This material should prove satisfactory for macadam construction subject to light or medium traffic, or for use with an artificial binder."

The siliceous dolomites in the lower portion of the Stones River Formation on the Security property, and the Beekmantown dolomite on the National Limestone Company tract two miles south of Martinsburg were tested with the following results:

	Security	National.
Specific gravity	2.85	2.85
Weight per cubic foot (pounds)	178	178
Pounds of water absorbed per cubic foot	0.37	0.26
Per cent. of wear	3.56	2.5
French coefficient of wear	11.2	15.9
Hardness	17.2	17.3
Toughness	17	13
Cementing value	Good.	Good.

"Fairly hard rocks, showing high resistance to wear, average toughness, and good cementing value. Should prove satisfactory for roads subjected to average traffic conditions."

A sample of the dark-blue limestone near the contact of the Bossardville and Helderberg Formations and apparently belonging at the former horizon was tested from the **Thompson and Downey farm** near the limestone cave a mile and a half south of Tomahawk:

Specific gravity	2.70
Weight per cubic foot (pounds)	168
Pounds of water absorbed per cubic foot	0.70
Per cent. of wear	5.4
French coefficient of wear	7.4
Hardness	13.66
Toughness	6
Cementing value	Very good.

"Suitable for use in the construction of macadam roads subjected to light traffic."

The following tests were made on the Upper Stones River Limestone from the quarries of the Standard Lime and Stone Company, at Martinsburg:

Specific gravity	2.70	2.70	2.70
Weight per cubic foot (pounds)	168	168	168
Pounds of water absorbed per cubic ft.	0.26	0.11	0.20
Per cent. of wear	4.8	4.1	4.2
French coefficient of wear	8.3	9.8	9.6
Hardness	16.7	15.7	16.4
Toughness	4	8	4
Cementing value	52	62	50

TESTS ON ROAD MATERIALS IN BERKELEY COUNTY, 1916.

With the cooperation of the County Court of Berkeley County and their Road Engineer, Mr. Geo. E. Showers, samples of road materials were secured at a number of localities in Berkeley County in the spring of 1916. These samples were tested by the U. S. Office of Public Roads at Washington with the following results:

Sandstones.

A sample of the Oriskany Sandstone was taken on the outcrop near the western base of Ferrel Ridge near Butts Store. This sandstone is composed of quartz sand with some ortho-

PLATE XXXVII.—View showing Flaggy Character of Catskill Sandstone in Doe Gully Cut of Baltimore and Ohio Railroad.

clase feldspar and contains kaolin and limonite which form the cement. It is therefore not a durable rock and has practically no value as road material. The Bureau tests are given below:

	Butts Store.	North of Tomahawk.	Hedgesville.	Inwood.
Specific gravity	2.25	2.50	2.65	2.30
Weight per cubic foot (pounds)	140	156	165	144
Pounds of water absorbed per cubic foot	3.45	1.66	0.62	3.19
Per cent. of wear	7.2	7.9	2.8	16.6
French coefficient of wear	5.6	5.1	14.3	2.4
Hardness	18.7	x	16.7	19.3
Toughness	6 to 14	x	15 to 22	2
Cementing value	Low	Low	Average	Low

The Oriskany Sandstone north of Tomahawk was also sampled. It is also composed of fine angular quartz grains cemented together by limonite (iron oxide) and silica. It is a more durable rock than west of the ridge but is not suitable for road material. It is an interesting outcrop in containing some minute tourmaline crystals, a mineral composed of boro-silicate of alumina, iron, and magnesia, and is a very rare mineral in the sedimentary rocks of this State.

A mechanical analysis of this sandstone was made by the Office of Public Roads and showed the following percentages:

	Tomahawk.
Quartz	89.4
Orthoclase feldspar and kaolin	6.0
Tourmaline	0.2
Limonite (hydrated iron oxide)	4.4
	100.0

The Hamilton Sandstone near the top of that Formation was sampled a mile west of Hedgesville on the county road. This is a feldspathic sandstone very compact and fine-grained. The Bureau at Washington found it to be composed essentially of angular fragments of quartz and kaolinized orthoclase feldspar, cemented together by secondary silica and kaolin, and suitable for use in the foundation course in macadam roads, and as an aggregate for concrete. The tests on this sandstone are given above and the mechanical analyses are as follows:

	Hedgesville.	Inwood
Quartz	48.6	87.[illegible]
Orthoclase and kaolin	47.4	4.4
Biotite (black mica)	0.8	.....
Limonite	2.6	8.6
Calcite	0.6	.....
	100.0	100.0

The Elbrook Formation is usually composed of limestones and shaly limestones and cherts, but in a number of localities there is a heavy sandstone horizon, well shown on Ferrel Ridge and also further south. A sample of this sandstone was taken one and a half miles west of Inwood on the county road to Gerrardstown and on the **McKown farm.**

This sandstone is described by the Office of Public Roads as a medium-grained, yellowish-brown, loose-textured sand-stone, composed essentially of rounded quartz grains, ce-mented together by iron oxide. It is of practically no use for road material. The tests and mechanical analysis are given above.

Helderberg Limestone.

The Helderberg Limestone was sampled on the west slope of Ferrel Ridge, just east of Butts Store, and also at a small roadside quarry just west of Tomahawk on this same Ridge. It was sampled further south on this Ridge toward Jones Springs, at the Joe Wheeler lime quarry. These lime-stones are all suitable for roads with light or moderate traffic and should be used on the roads of this section. The results of the tests are given below:

	Butts Store.	Tomahawk.	Wheeler.	Jones Springs.
Specific gravity	2.70	2.70	2.70	2.70
Weight per cubic foot (pounds)	168	168	168	168
Pounds of water absorbed per cubic foot	0.61	0.27	0.37	0.31
Per cent. of wear	6.2	4.5	5.7	4.4
French coefficient of wear	6.5	8.9	7.0	9.1
Hardness	14	18.3	14	17.3
Toughness	4	15	4	9
Cementing value	Average	Average	Average	Average.

The sample labelled Jones Springs is also from the Wheeler quarry, but it is a siliceous, hard, dense, blue limestone, while the other sample was quite crystalline. The two quarries appear to be at different horizons in the Helderberg Limestone Formation.

Conococheague Limestone.

This Cambrian Limestone was sampled at two places, but its outcrop covers a wide and long area in the county and also in Jefferson County.

In the northern part of Berkeley County near the river in the vicinity of Little Georgetown, this limestone has been extensively used for road material, and is well adapted to this use. A sample was taken near the county road just east of this village. Another sample was taken near the road which passes under the main line of the Baltimore and Ohio Railroad at the north end of Cumbo Yard, or about two miles south of North Mountain Station:

	Little Georgetown.	Cumbo Yard.
Specific gravity	2.80	2.75
Weight per cubic foot (pounds)	175	172
Pounds of water absorbed per cubic foot	0.37	0.52
Per cent. of wear	6.5	4.6
French coefficient of wear	6.2	8.7
Hardness	18.7	16.7
Toughness	10	4
Cementing value	Low	Average

Beekmantown Limestone.

The Beekmantown Limestone outcrops over large areas of Berkeley and Jefferson Counties, and it is quarried for road material and railroad ballast. Samples of this limestone were taken at a number of places for the tests.

One sample was taken from a small roadside quarry a half mile north of Spring Mills. It here occurs in solid ledges of dark-blue to bluish-gray limestone, and it has been used on this road for a number of years. Another sample was taken just east of Nipetown on the road across to the Williamsport

Pike. This limestone was sampled about two miles east of Bedington across Opequon Creek on the road to Whitings Neck. A sample was taken of the hard, blue dolomitic limestone on the National Limestone Company tract to the west of the working quarries, which are in the Stones River horizon. This location is two and a half miles southeast of Martinsburg. A sample was taken of the Beekmantown Limestone about two miles west of Inwood on the road to Gerrardstown, but here the rock is quite slabby, almost shaly.

The tests as given below and made by the U. S. Office of Public Roads show this limestone adapted to use on these country roads, and there is a large quantity available well distributed over the county:

	Spring Mills.	Nipe-town.	Whitings Neck.	National.	Gerrards-town.
Specific gravity	2.70	2.70	2.75	2.85	2.75
Weight per cubic foot	168	168	172	178	172
Poundes of water absorbed per cubic ft.	0.27	0.43	0.19	0.31	0.46
Per cent. of wear	4.2	4.9	4.9	3.6	6.5
French coefficient of wear	9.5	8.2	8.2	11.1	6.2
Hardness	15	16	16	16.3	15.7
Toughness	4	3	10	10	-9 to -15
Cementing value	Average	Average	Average	Average	Low

Stones River Limestone.

The Upper Stones River Limestone is a very pure rock, and quite brittle. It is the valuable steel furnace flux limestone, and the large quarries of the Martinsburg section are in this limestone. The smaller sizes from the crusher are sold for road material and for concrete. A number of samples were taken and tested at the Washington laboratory. The tests show this limestone is adapted to use on roads subjected to light traffic. One sample was taken from the quarries of the Security Cement and Lime Company, at Berkeley Station, four miles north of Martinsburg. Samples were also taken from the Blair Limestone Company quarries at Blairton, three miles east of Martinsburg; and from quarries of the National Limestone Company, two miles southeast of Martinsburg. A sample was taken from the Rutherford farm, just east of

Darkesville, or seven miles south of Martinsburg; also from the quarries of the J. E. Baker Lime Company, at Bunker Hill, ten miles south of Martinsburg:

	Security.	Blair.	National.	Darkes-ville.	Bunker Hill.
Specific gravity	2.70	2.70	2.70	2.70	2.70
Weight per cubic foot. (pounds)	168	168	168	168	168
Pounds of water absorbed per cu. ft.	0.27	0.23	0.56	0.31	0.24
Per cent. of wear	6.3	5.9	5.8	5	5.1
French coefficient of wear	6.4	6.8	6.9	8	7.8
Hardness	16	16.3	18	15	16
Toughness	4	5	5	4	4
Cementing value	Average	Low	Average	Average	Average

Chambersburg Limestone.

Over the Stones River Limestone is the Chambersburg, which on weathered outcrop shows a cobbly, weathered structure. Many of the ledges are marked by criss-cross clay seams and so weather to cobbles. Below the surface ledges are more solid limestones, but they usually break in blocks two to eight inches thick. The limestone is hard and rather close-grained and is used on many of the county roads with good results.

A sample of this limestone was taken from an old abandoned railroad quarry, a half mile northeast of Falling Waters. The stone was badly weathered and no pieces were secured large enough for tests on hardness or toughness, Another sample was taken from a small roadside quarry west of the main pike and about a half mile northwest of the Falling Waters Schoolhouse. A sample was taken just across the stone bridge over Opequon Creek on the Shepherdstown road near Blairton and about two and a half miles east of Martinsburg. The county opened a quarry on the **Van Metre farm** near forks of road south of Van Metre Schoolhouse, two miles southwest of Van Clevesville. The tests on these samples made by the U. S. Office of Public Roads show the limestones to be suitable for these roads:

	Railroad Quarry	Falling Waters	Opequon Bridge	So. of Van Clevesville
Specific gravity	2.70	2.70	2.70	2.70
Weight per cubic foot (pounds)	168	168	168	168
Pounds of water absorbed per cubic foot	0.59	1.27	0.19	0.36
Per cent. of wear	5.6	4.7	5.1	5
French coefficient of wear	7.1	8.5	7.8	8
Hardness	x	16.7	16.7	17
Toughness	x	8	6	9
Cementing value	Average	Low	Average	Average

TESTS ON JEFFERSON COUNTY ROAD MATERIALS.

In the broad belt of Beekmantown Limestone across Jefferson County, there are numerous roadside quarries, and the large ballast quarry at Kearneysville. This limestone is available for roads over a large area of the county. The following tests were made on this limestone at different points in the county and they are given in the reports of the U. S. Office of Public Roads. The first series of tests listed below is on the limestone from the large ballast quarries of the Standard Lime and Stone Company at Kearneysville; the second series is on the same limestone near this town; the third is from Middleway, and the fourth from near Summit Point:

	Kearneysville. Standard.	Hale.	Middleway.	Summit Point.
Specific gravity	2.70	......	2.70	......
Weight per cubic foot (pounds)	168	172	168	175
Pounds of water absorbed per cubic foot	0.22	0.63	0.72	0.32
Per cent. of wear	3.9	4.2	4	2.9
French coefficient of wear	10.2	9.6	10.1	13.8
Hardness	14.3	14.7	15.8	17.5
Toughness	6	5	10	22
Cementing value	29	68	26	35

According to these tests these limestones have medium hardness and low toughness except the Summit Point rock which is high, with medium resistance to wear, and fair cementing value. They are adapted to roads with medium traffic, and represent a good type of county road material.

The Beekmantown Limestones were also tested to the east of Leetown on the **Chew and Wiltshire farms** with the ving results:

Specific gravity	2.70	2.70
Weight per cubic foot (pounds)	168	168
Pounds of water absorbed per cubic foot	0.19	0.33
Per cent. of wear	4.1	3.5
French coefficient of wear	9.7	11.4
Hardness	16.8	15.8
Toughness	7	10
Cementing value	94 (Very good)	Good.

The Waynesboro Limestone was tested from the quarry of the Potomac Lime and Stone Company, at Engle Station, and the dolomites from the Millville quarries of the Standard Lime and Stone Company:

	Engle.	Millville.	
Weight per cubic foot (pounds)	168	175	178
Pounds of water absorbed per cubic ft.	0.30	0.74	0.29
Per cent. of wear	4.5	4.4	3.7
French coefficient of wear	9.0	9.1	10.9
Hardness	11.8	14.3	16.6
Toughness	4	7	6
Cementing value	41	24	28

CHAPTER XVIII.

IRON ORES AND OTHER MINERAL RESOURCES OF THE EASTERN PANHANDLE.

IRON ORES.

Limonite iron ore nodules are found here and there over the limestone area of Berkeley and Jefferson Counties. In some of the fissures of the limestone they may become quite abundant in a narrow belt which may follow the trend of the limestone for considerable distances. They represent a concentration of the iron from circulating waters, and are usually quite high in silica and low in iron content. Selected nodules of good weight will show an iron content above the average. These nodules are found on many farms in the area and they are often regarded by the landowner as a valuable asset of the farm, and inquiries are often made as to their value. The total quantity is never large and there is no encouragement that they would continue to any depth or increase in amount with depth. The quantity seen on the surface of the farm is a good indication as to total quantity and would very seldom be worth mining or handling. They are also low in average content of metallic iron. It must be remembered that iron ores with less than 45 per cent. iron and of this grade ore would not be marketable at the present time except under very unusual conditions. Many of these ores run as low as 20 per cent. iron and the highest found was less than 40 per cent. iron with nearly as much silica.

Jefferson County.—The only operating iron mine in the State of West Virginia at the present time is located on the Potomac River in Jefferson County, four miles above Harpers

Ferry at a point named Orebank, and it is reached by a switch from the Baltimore and Ohio Railroad from Engle Station by way of the Bakerton limestone quarries. This mine was opened about 100 years ago, and is now owned and operated by Joseph E. Thropp, of Everett, Pennsylvania, who ships the ore to the furnace at Earlston across the river from Everett, where it is mixed with Lake ores.

This ore at Orebank is mixed with the red clay forming the surface cover, 1 to 20 feet thick, over the limestone on many acres in this region. The open fissures of the limestone, 2 to 25 feet in width, are filled with this same mixture of clay and ore, and they have been worked out to a depth of 140 feet in one place. In these fissures also occur ledges of boulder brown hematite reaching a maximum thickness of two feet. The surface clay and ore are also mingled with sandstone and flint water-worn boulders which represent an old river terrace in past time.

This mixture of clay and ore is washed in two double log washers, 30 feet long and 7 feet wide, which give a capacity of 40 to 50 tons daily, and much of the clay is thus removed. The working force includes about 50 men and a small engine is used to haul the ore from the pits to the washing plant. Most of the ore shipped is the washed clay ore, but the boulders of ore from the fissures are also loaded and form a very small part of the shipped ore.

The following analyses were made in the Survey laboratory of the boulder ore and the washed clay ore:

	Jefferson County. Lump Ore.	Jefferson County. Washed Ore.	1915. Lump Ore.	Berkeley County.	Shenandoah Ore.
Moisture	0.27	0.40	0.82	.....	0.77
Loss on ignition..	10.03	9.88	10.63	.....	10.03
Silica	20.75	19.70	5.94	35.98	13.96
Iron oxide........	58.87	63.04	78.29	55.17	72.61
Lime oxide.......	0.26	0.20	.....	.....	.....
Manganese dioxide	1.40	0.39	.....	.....	.....
Sulphur	0.02	0.03	.....	.....	.....
Phosphorus	0.31	0.28	0.29	.....	0.11
Titanium oxide....	0.21	0.05	.....	.....	.....
In Metallic Iron...	41.21	44.14	54.77	38.63	50.80

Just east of the Shenandoah River, south of Harpers

Ferry, across the county, there is a series of iron ore deposits near the contact of the limestones and the Harpers Ferry Shale. This ore was worked at the old Shenandoah furnace which is still standing a short distance up the road at Shannondale Ferry. A sample of the ore was taken from the old pits and its composition is shown in the above table. Its iron percentage, 50.8, is high for a brown hematite ore, and there is apparently a very considerable tonnage yet available in this section.

The washed ore is of fairly high iron percentage and the impurities are low except the silica. The phosphorus is too high for a Bessemer steel but could be used in the open-hearth process. This washed ore is very close to the average composition of the West Virginia iron ores. This average showed 43.86 per cent. metallic iron and 19.48 per cent. silica, as determined from 70 samples taken in the different iron ore districts of the State.

Berkeley County.—Just south of Martinsburg on the **Faulkner farm,** near the limestone quarries of the Standard Lime and Stone Company, prospect pits were sunk many years ago to a deposit of brown hematite or limonite iron ore which attracted considerable attention at that time and some of the ore was shipped away. This ore is representative of the various deposits of iron ore reported from the farms through the county, though it is of even better grade than many of them.

The ore is a limonite, more or less sandy, and found in honeycomb nodules full of dirt or clay, and also in the form of pipes. It is irregularly distributed and apparently not in any solid body. In its mining there would have to be moved much more dirt than ore, and probably at no great depth the ore would play out, as its formation is due to surface agencies.

As the pits are followed to the west to the more siliceous and magnesian limestone outcrop, the ore seems to disappear. Similar deposits are reported north of town to the west of the Security quarries, and the ore appears to follow a line some 600 to 1,000 feet west of the high-grade limestone. Some iron like nodules are found in the shales and often are called iron ore nodules. They contain a very small amount of iron usually in the form of sulphide and have no value. Scattered nodules of loose texture limonite or bog ore occur throughout the limestone area and appear to follow no regular line.

Morgan County.—Back of Sir Johns Run Station in Morgan County are outcrops of the Clinton red hematite iron ore which was mined some years ago on a very small scale. This ore is said to have been rather high in metallic iron and of very good quality, but the seams were narrow, one being six feet and the other two feet wide.

The following analysis shows the composition of this Clinton ore from the old pits three-fourths mile south of Sir Johns Run Station:

	No. 189
Moisture	1.66
Loss on ignition	7.53
Silica	22.69
Iron oxide	57.87
Lime oxide	0.22
Phosphorus	0.41
In Metallic Iron	40.48

The Clinton Formation usually carries these seams of iron ore and in some other parts of the State they reach a valuable size but are there undeveloped for lack of railroad outlets. The Clinton ore is the basis of the great iron and steel industry in Alabama. It will be a long period of time before these ores described above will have any market value, and at the present time they are interesting deposits rather than valuable. There are very valuable deposits of iron ores in the Counties of Hardy, Hampshire, and Pendleton, and the natural outlets for these ores would be through the eastern Panhandle Counties. If railroads are built to these ores they will probably reach the main line roads in some one of these three counties, and then either be shipped to outside steel plants, or be worked into iron and steel products in this area

The Eastern Panhandle—A Logical Field for Iron and Steel Industries.

The writer two years ago prepared an article for the

Manufacturers Record calling attention to the natural advantages of this district for iron and steel industries, and some of these factors will here be repeated:

"West Virginia is one of the greatest fuel States in the Union, and yet three-quarters of this fuel is utilized in the manufacture of valuable commercial products in other States, causing its own rank to fall to 29th place in value of manufactured products. It ships 5,000,000 tons of coal to other States for the manufacture of coke in those districts for iron and steel furnaces. West Virginia coal is in large demand in these other States for iron and steel manufacture, while at the same time there are present in the State attractive and most favorable conditions for the location of plants of large size. It does seem strange that the great opportunity for such work does not result in greater development of these industries at home.

"The iron and steel industries are rapidly increasing, and new sources of ore are being developed in this country, and also in the countries to the south due to the Panama inlet for such ores. With the advent of these coastwise shipments and their lower cost ores, there is a tendency to the shifting of iron and steel centers, and a consideration of plans for new plants on gigantic scale, which leads one to wonder if the famous Pittsburgh district will in the future so largely dominate this industry as it has in the past. In this shifting of centers, eastern West Virginia offers a most inviting field for the location of new plants, with its natural and logical advantages for this work.

"The three requisites for the manufacture of iron and steel are—iron ore, fuel, and flux. At practically all the Northern iron and steel districts, all of these requirements are shipped in from more or less distant points, and the finished products are shipped out to more or less distant demand centers. The freight rates from this eastern Panhandle district would be lower to eastern cities and to tide-water for export than from Pittsburgh, and as to low as from many of the other Pennsylvania centers. The transportation feature is therefore favorable to this district.

"**Iron Ore.**—The supply of iron ore for the Pittsburgh district, Johnstown and the Ohio Valley plants, come almost entirely from the Lake Superior iron mines. In the mountain counties of this State are large deposits of brown hematite iron ores, approximately estimated at 185,000,000 tons, which only wait for development on the construction of short line railroads to connect with main line roads. This source would supply ore to furnaces in this area over short hauls with the resultant low freights. While these ores are too high in phosphorus for Bessemer steel, they are suitable for open-hearth steel of which the output is now more than double that of Bessemer.

"Another factor to be seriously considered is the possibility of using Cuban ore, or even Chile ore in this section, through the opening of the Panama Canal. These Cuban ores are now in successful use at Baltimore and Steelton. Wm. Hard in articles on American business conditions stated a few years ago that 'for the ore from which pig iron is made, the boundary line between Cuba and the United States zigzags through the United States from a point on the St. Croix River in Maine to a point on the Rio Grande in Texas.' He further stated that the placing of iron ore on the free list, thereby removing the 12 cents per ton duty, would push this line further westward so that 'Cuban ore will soon travel well into midmost Pennsylvania before smashing itself against the lower costs of the native ore coming down from the head of the Great Lakes.'

"A comparison of ore costs at Johnstown, Pa., will illustrate this viewpoint set forth in the above quotation. Lake Superior ores cost at Johnstown $4 per ton plus $2.27 freight or a total of $6.27. Cuban ore at $4 and freight rate of $1.00 by water and $1.40 by rail, gives a total cost at Johnstown of $6.40. At Harrisburg, Pa., the cost of Cuban ore is 70 cents per ton less rail freight than to Johnstown, or a total cost there of $5.70 which is 57 cents a ton less than the cost of Lake Superior ore at Johnstown.

"A comparison of analyses of these two districts is not unfavorable to the Cuban ore. Lake Superior ores run 46 to 56 per cent. metallic iron with silica 2 to 6 per cent. and phosphorus 0.04. Cuban ores run 45 to 52 per cent. metallic iron, 2 to 5 per cent. silica, and 0.01 to 0.03 phosphorus. The Government engineers, after an examination of three of the Cuban properties, estimated that they contained 1,500,000,000 tons of available ore. About 1,500,000 tons of these ores are imported a year. These ores could be brought to this portion of West Virginia as low and possibly lower cost than the Lake Superior ores at western Pennsylvania centers.

"**Fuel.**—The most important mineral product in this State is fuel. At the present time heat for the open-hearth steel furnace is usually supplied as producer gas made from coal. Coal for this purpose should be high in fixed carbon and volatile combustible matter. The best coal for such work is the Pittsburgh seam and the best portion of this seam for gas manufacture is in the Fairmont area (W. Va.). Two to four producers are required for each furnace, the number depending on the size of the furnace and on the style of producer. By this process about 550 pounds of coal are required per ton of steel.

"In the blast-furnace reduction of ore to pig iron, coke is the most common fuel. It requires nearly a ton of coke to the ton of pig iron. The average in the Pittsburgh district is around 1,800 pounds of coke. West Virginia contains valuable mines of coking coal in the Fairmont region, Upper Potomac area, and in the New River and Pocahontas fields. The total production of coke in the State is about two and a half million tons and nearly twice that amount is made from West Virginia coal in other States.

"Nearly all the State plants are equipped with the old-time beehive ovens, while the coke from this coal made in other States was in by-product ovens so that the gas, tar, etc., are saved. Connellsville coke in the Pittsburgh district costs $1.90 plus 70 cents freight, or a total of $2.60 a ton, while Fairmont coke delivered in this eastern area would cost $3.50 a ton, but this cost would be greatly reduced by shipping the coal to by-product plants in this same area, and the resultant cost would be little more, if any, than in the Pittsburgh district.

"The Pittsburgh iron and steel industry has resulted from natural conditions, being central to the large area of Connellsville coking coal, and 150 miles from lake ports which are reached by the ore laden vessels with their low water tariff, natural conditions that are now almost duplicated by West Virginia locations. But the great Connellsville coking field seems to have reached its culmination in production, and experts have predicted its exhaustion within the next

20 years. Each year a number of ovens are abandoned and new tracts sought for development. With a decreasing supply there will follow an increasing cost, and the supply of coal and coke from this State will be drawn upon more and more. These West Virginia coals are now shipped to Ohio, and even as far West as Gary, Indiana, for the steel furnaces. Necessity has caused the coal of this State to follow the steel furnaces, why not the reverse, that the steel furnaces locate nearer the coal supply?

"**Limestone Flux.**—It requires 1,000 to 1,500 pounds of limestone to flux one ton of Lake Superior ore in the blast-furnaces at Pittsburgh where nearly three million tons are used annually. It requires 180 to 200 pounds of very pure limestone to the ton of steel in the open-hearth furnaces. The available quantity of high-grade limestone in the eastern counties of West Virginia is practically unlimited, and is shipped in large quantities to the Pittsburgh District. The limestone is sold at 55 cents a ton and the freight rate to Pittsburgh is 65 cents a ton, or a total delivered price of $1.20 a ton, and it has been shipped to central Ohio with a freight rate of $1.40 a ton. Iron and steel plants located in this section would secure their supply of fluxing stone without freight, thus saving this item of expense.

"The natural advantages for the location of iron and steel plants in this portion of West Virginia are most favorable. Such plants would be located near the fuel and flux deposits, with a source of native ores close at hand, and Cuban and South American ores costing delivered no more than the ores at Pittsburgh. The cost of the raw materials for a ton of pig iron in the two districts at the present time using Cuban ores in this section would be approximately:

	Pittsburgh.	Martinsburg.
Iron Ore	$ 9.25	$ 9.00
Coke	2.10	2.80
Limestone	0.75	0.40
	$12.10	$12.20

"In this estimate the cost of limestone was figured as obtained close at hand in the two localities, there being a slight freight charge in the Pittsburgh district and none at Martinsburg as the plants could be located near the limestone. By the use of by-product ovens at the eastern plants the coke cost would be lowered, so that the actual cost would be less than at Pittsburgh. There should also be taken into account, the lower freight rates from this West Virginia location to eastern markets and to tide-water, which would be a very important item in competition with the western Pennsylvania plants.

"With the rapid growth of the American iron and steel industry, and with the advent of low cost ores at the Atlantic border, new iron and steel plants will doubtless be constructed in the East, and of all the available localities, it would be almost impossible to find one with greater natural advantages than this eastern section of West Virginia, which is the logical field for iron and steel industries."

BUILDING STONE.

In Morgan County there is a variety of sandstones and limestones available for building stone. The Pocono hard sandstones would prove most durable in construction, though rather hard to work. The Purslane member was quarried at one time near Orleans for use in bridge piers on the Baltimore and Ohio Railroad. There is another group of these hard sandstones in the Medina Sandstone of Cacapon and North Mountains, and also the Keefer Sandstone. Through the Devonian Shales occur sandstones which are soft and probably less durable in heavy work, but which are used locally for foundations of houses and barns. The Oriskany Sandstone is too friable for building stone in most of its outcrops. In this county also occur the limestones of the Helderberg and the more flaggy Bossardville. These have been used for foundation work and also in building stone houses. No large quarries have been opened in the county but the stone is quarried as needed from small openings. The sandstone near the top of the Hamilton is very hard and resistant with a greenish cast and is available in many sections. There are also some very pleasing shades of red sandstone in the Catskill as well as green sandstones which come out in large blocks. This massive phase of the Catskill Sandstones is well shown in the new cuts of the railroad in the western part of the county. The color does not appear to be permanent and the rock tends to weather shaly, which would be the disadvantages of this rock.

In Berkeley County the main source of building stone would be the limestones, which are available almost everywhere. This limestone in very old buildings shows its resistance to the weather and proves it to be a most durable stone. It occurs in various shades, white, blue, and black. It is a hard rock, but readily worked into shapes. The pure limestone makes a very pleasing stone, and has been used in a number of buildings at Martinsburg, but it is difficult to work into shapes on account of its brittle character, as it spalls badly under the hammer. In the lower limestone formation, the Conococheague, are masses of oolitic limestone that would probably work into ornamental finish stone. The oolite limestone of Bedford County, Indiana, is shipped in car-load lots all over this country, and there is a constant demand for it as an ornamental trimming stone, even with its high freight cost.

These Berkeley County oolitic limestones are much harder than the Indiana stone and would not work to as good advantage on account of the hardness, but they offer an opportunity to secure an artistic finish, and when polished, almost a marble effect.

There are a number of old limestone buildings in the county dating back a hundred years or more, and the stone looks like it had been recently quarried. At the present time very little limestone is quarried in the county except for foundation work. On North Mountain there is a red to deep-brown sandstone of the Medina Formation that would appear from some of its outcrops to be durable.

In Jefferson County, the limestones are also available and have been used in many old stone houses and for foundations. The Antietam and Weverton Sandstones are hard and apparently durable rocks. In this county there are no large building stone quarries and the stone is obtained as needed for local use from small openings. White and bluish-white marbles occur through the Waynesboro Formation.

Building stone in great variety and in abundance is available in the three counties, but the development of this industry so far is very small, and there are no large building stone quarries, so no shipments out of the counties. There is an opportunity for a large business along this line, and if quarries were opened on some of these sandstones and limestones and the products properly advertised, doubtless a profitable business would result. The working of some of the ornamental trimming stone is worthy of an investigation.

COMMERCIAL SLATE.

The Martinsburg Shale in 1904 and 1905 attracted some attention as a basis of a possible slate industry. Several companies were organized and options taken on lands available to the railroad. A considerable amount of money was expended and finally the companies allowed their options to expire and interest waned. The most extensive development was made by the **Shenandoah Slate Company**, of Washington, D. C., which opened a quarry 65 feet deep and equipped a small mill with sawing, grinding, and polishing machinery. The slate was used in interior construction work with satisfactory results. Large slabs were obtained and took a good polish. When exposed to the weather the slate showed a tendency to crack and disintegrate on the surface, giving a cracked and scaly appearance. It was hoped by the promoters of the industry that the quality would improve with depth, and that a good quality of roofing slate would thus be found. The process of alteration of the shales into slate by the pressure involved in the folding of the rocks was evidently not complete enough to form a roofing slate. All the available evidence appears to be conclusive that these so-called slates are without value as roofing slate, but would probably have a value for interior work as structural slate. Whether it would be profitable to establish works for this purpose alone is ver doubtful when taken in competition with the long-established works in Pennsylvania and other eastern States.

The chemical composition of this slate from the deep quarry at 65 feet is shown in the following Survey analysis, and for comparison an analysis of the famous Peach Bottom, Pennsylvania, slate, as made by McCreath, is added:

	Martinsburg.	Peach Bottom.
Silica	53.30	55.88
Alumina	18.16	21.85
Iron oxide	6.53	9.03
Lime oxide	4.89	0.155
Magnesium oxide	2.65	1.495
Sodium oxide	0.52	0.46
Potassium oxide	3.70	3.64
Titanium	0.24	1.27

The silica-alumina ratio in the Martinsburg slate is 2.93 to 1, and in the Peach Bottom slate, 2.55 to 1. The magnesia, and especially the lime, are higher in the Martinsburg slate, and the lime is probably to a large extent responsible for the cracking of the slate on weathering. Except for the lime there is quite a resemblance in the chemical composition of the two slates, and the great and important difference except in the lime is probably to be found in the physical structure in the much less complete alteration of the shale into slate in the Martinsburg area.

In 1906 Mr. T. Nelson Dale published a bulletin on the slate deposits of the United States and gave therein a brief account of these so-called slates in West Virginia. This account was included in Bulletin 275 (pp. 119-122). The description was repeated in Mr. Dale's second bulletin on this subject issued in 1914 by the U. S. Geological Survey (No. 586, pp. 164-166), in which he holds the same opinion of the value of the deposits as given in the first bulletin. A reprint of this article is given in the West Virginia Geological Survey report, Volume IV, pages 392-396.

Mr. Dale described the deep slate quarry of the Shenandoah Slate Co., as examined in May, 1904. It was 100 feet long on the strike (northeast-southwest), 70 feet wide, and 75 feet deep, the surface weathered portion extended down for 25 feet. The strike of the slate or shale was N. 25° E., and dip of 15 degrees S. 65° E. The cleavage planes dipped in the same direction 75 degrees. He stated the slate beds were small and separated by darker ribbons, the thickest bed being 3 feet 6 inches. A diamond drill hole put down 40 feet below the bottom of the quarry showed several three-foot beds. The analysis of the material showed a lower lime percentage than the samples tested in the Survey laboratory as given above. He found 1.11 per cent. lime oxide and 62.71 per cent. silica, with 19.40 per cent. alumina. He describes the different openings around Martinsburg and found they varied in lime percentage at different places, but this element was usually rather high, and he found the amount of crystallization in the slates but slight as examined by the microscope.

Mr. Dale describes the slate in the deep quarry mentioned above as follows:

"The slate is black, with a slightly brownish hue. The texture is somewhat fine and the cleavage surface roughish, without any lustre whatever. The material is carbonaceous rather than graphitic, contains a little magnetite, shows pyrite on the sawn edge, effervesces with cold dilute hydrochloric acid but less in the ribbon, is somewhat sonorous, and has an argillaceous odor. Under the microscope, it shows a matrix consisting of carbonate and carbonaceous matter, and therefore without aggregate polarization, but a cleavage consisting in the parallel arrangement of the carbonate and carbonaceous matter in alternating bands. A very carbonaceous bed (ribbon) crosses the cleavage at an angle of 36 degrees. There are abundant angular quartz grains up to 0.05 millimeter; scales of chlorite interleaved with muscovite, and some of muscovite only; spherules of pyrite up to 0.01 millimeter, numbering from 6,500 to 11,000 to the square millimeter. Rutile was not observed. The amount of carbonate differs in different beds. It may be so abundant as to completely obscure the sericitic matrix. Some of the sections parallel to the cleavage show almost as much muscovite as carbonate, and, curiously, a faint aggregate polarization parallel to the bedding or the grain.

'The constituents of this slate, named in descending order of abundance, appear to be, muscovite (in places almost equal in amount to carbonate), quartz, kaolin, pyrite, carbonacous matter, chlorite, and magnetite. This is a clay slate. The amount of carbon dioxide in this slate was determined by George Steiger, of the United States Geological Survey, at 1.94 per cent."

Mr. Dale concludes from his studies on these slates near Martinsburg that:

"Although the proportions of carbonate and muscovite vary in these slates, none of them show a complete sericitization of the matrix. They are all clay slates. The material can therefore hardly possess sufficient fissility or prove sufficiently strong or elastic to compete with mica slates for roofing. Furthermore the amount of carbonate shown by the microscope, as well as the mode of weathering in the outcrops, indicates its probable discoloration on prolonged exposure, so that it belongs in the 'fading' group of clay slates. But these characteristics do not affect it serviceableness for indoor uses."

Mr. Dale is the slate expert of the Government Survey and is probably the best-posted man in this country on the subject and value of slates, having had long years of experience in this work. He made a most careful study of this field, visiting all the most promising openings, and his conclusions are to be accepted. It is unfortunate that the slates did not prove as valuable as the promoters of the companies had hoped. There is to-day an impression among some of the owners of these slate lands that they will yet prove valuable roofing slates, but other uses for these shales must be sought, and they will be found in the manufacture of cement, and the surface portions at least are valuable for brick manufacture.

SAND AND GRAVEL.

Outside of the great sand industry at Berkeley Springs described in a preceding Chapter, there are other sources of building sand. In many parts of the area, the Oriskany Sandstone quarried at Berkeley Springs is found on outcrop to be weathered to sand or in a crumbly state so it could be readily crushed. It is too high in iron for glass-sand in these other sections, but would make a good building sand.

In some of the mountain outcrops the Purslane Sandstone has weathered to a sand quite white in color. The Medina White Sandstone also in places weathers to a nearly white sand. Some of the impure brown or buff sandstones of the Devonian and other formations of the area crumble to a brownish sand of good grit and suitable for building sand. Sand is used in Martinsburg as building sand that is secured from the weathered sandstones along the upper slopes of North Mountain. There is thus available a large amount of building sand at various places in the area, though they are only used periodically for a few buildings here and there near the outcrops or with short wagon haul. Most of the building sand used in the towns and cities is shipped in from Berkeley Springs or from the river sand works on the Maryland side of the Potomac near Williamsport Station.

In many of the creek valleys there is a deposit of sand that is also used locally. Near Harpers Ferry considerable sand has been obtained from the river and shipped to other points in the area. The Berkeley Springs sand costs at Martinsburg 75 cents a ton plus 40 cents freight or a total of $1.15.

River gravels are found at various places on high level terraces along the Potomac and Shenandoah. Some of these gravel deposits appear to have good depth and with the elevation above the railroads could be loaded by gravity. A gravel washing plant with screens would furnish an abundant and cheap supply of this gravel for various lines of concrete work. In Baltimore and Washington large quantities of gravel are used in concrete, and the industry is prominent in many sections of the country. Some engineers prefer gravel for concrete and claim it makes a stronger body. The low prices on gravel would probably not permit it to be shipped to any distant points, but it should prove valuable for local use and could be shipped short distances. No attempt has ever been made to develop this industry in this area.

In the Waynesboro and Elbrook Formations, there are outcrops of soft, light weight, yellow sandstone, which crumbles between the fingers and resembles a tripoli or polishing sand. On analysis it is found, however, to run high in magnesium and alumina.

Sample No. 150 is from the Elbrook Formation about one mile southwest of Uvilla in Jefferson County. No 175 is also from the Elbrook, and it was taken just east of the Berryville road, one and a half miles due south of Charlestown:

	No. 150.	No. 175.
Silica	57.33	54.81
Iron oxide	6.10	6.85
Alumina oxide	19.06	14.99
Lime carbonate	1.87	2.64
Magnesium carbonate	12.29	21.22
Loss on ignition	3.65	......
	100.30	10.51

WATER-POWER.

The various streams of the area coming from the higher lands of the mountain districts have a high rate of fall, but usually a fluctuating volume. In their stage of high waters they would furnish much power, but it would not be reliable unless dams were constructed in the mountain areas to hold back this surplus water and so give a uniformly distributed supply. Under these artificial conditions, there would be available water-power in many sections.

In a few places large springs have been used to furnish power by an overshot water-wheel for farm use, with the resulting convenience and value to the owner. One of these is seen near Ziler Ford in Morgan County, and another at Harland Spring in Berkeley County. There are a number of large springs in the area that could be used in a similar way at little cost and would be of much service on the farm.

Cacapon River has good fall and a large volume of water and would furnish water-power at various places along its line. It is used at present a short distance south of Great Cacapon Station by the Northern Virginia Power Company. At this place there is a large and narrow horseshoe bend which is cut through near the beginning of the bend by a tunnel and ditch or canal. A 15-foot dam in the river channel impounds the water and deflects it through this tunnel with a resultant fall of 18 feet. The power-plant generates 750 horse-power and the current is transmitted to Great Cacapon, Berkeley Springs, Hancock, and Martinsburg, and the small towns along the way.

On the Potomac there are two electric power-plants operated by the Martinsburg Power Company. One of these is northeast of Little Georgetown, and the other near Shepherdstown.

On the Potomac below Shepherdstown the old cement mill had a dam which furnished 1,000 horse-power, and if built higher would give a considerable increase in power. No use is made of this dam at the present time.

On the Shenandoah River above Millville in Jefferson County, the Northern Virginia Power Company, of Winchester, has a large electric power-plant and furnishes power and lights to Charlestown, Winchester, Martinsburg, and various towns in the two counties as well as to different quarries.

This electric power available in this eastern area means much to the convenience and pleasure of its citizens, and also offers great advantages to the location of manufacturing plants. The present companies have an abundant supply of this power and for further safety in furnishing a regular supply to their consumers, they have established steam auxiliary plants to supply the current in case of low water, or other accidental conditions which would interrupt their river power service. The power is supplied at very reasonable cost, and the companies using the power have had no cause for complaint by failure of current.

As to comparative cost of this power with that of coal, the writer made some calculations for a limestone operation a few years ago, based on a daily output of 3,000 tons of stone, and the results follow:

Direct Steam Power.—In the use of direct steam power with Georges Creek Coal from Cumberland, costing at Martinsburg $2.80 a ton, it would require 400 pounds of coal to the hour for 100 horse-power.

A 3,000-ton daily capacity limestone plant would require 700 horse-power, which would then consume 14 tons of coal in ten hours. In addition, the banking of the fires at night (14 hours) would require about one pound of coal per horse-power an hour, or 14 pounds each night per horse-power in this size plant. This would amount to 4.9 tons (9,800 pounds), or a total daily coal consumption of 18.9 tons. This coal would cost about $2.80 a net ton, as the extra pounds on the gross ton would about equal the cost of unloading the coal from cars.

The cost then for coal in this 3,000-ton plant daily would be $52.92, or 1.764 cents a ton. This steam plant would cost at least $50,000, on which there would be the following annual fixed charges:

	Per cent.
Depreciation	5
Interest	6
Taxes	1
Repairs	1.5
	13.5

Fixed charges then would be $6,750 a year, or daily, $22.50.

There would also be the running charges of an engineer ($90 a month), fireman at $1.50 a day, oil at $5 a month, supplies at about $10 a month, or a total annually of $1,230, or daily, $4.10. The total charges or cost on a 3,000-ton plant per day, and per ton of stone would be:

For Coal	$52.92
Fixed Charges	22.50
Running Charges	4.10
	$79.52, or .0265 per ton of stone.

By use of a **steam turbine plant,** the cost of the plant would be about $60,000, making the fixed charges $8,100 a year with running charges about the same as in the steam plant. The fuel consumption would be decreased to about 12 tons a day for this size stone plant. The total daily cost would be $60.20, or 2 cents a ton of stone.

By use of **purchased electric power,** the necessary motors would cost about $15,000 which with interest and depreciation of 12 per cent. a year would make the fixed charges $1,800 a year or six dollars a day. The power required daily would be approximately 1,650 kilowatt-hours, and at a price of 2 cents per K. W.-hour would cost daily $33.00. The daily cost of power including the fixed charges would be $39.00, or 1.3 cents per ton of stone.

The cost then of power by the three methods would be as follows:

Direct steam power	2.65	cents per ton of stone
Steam Turbine	2.0	cents per ton of stone
Purchased electric power (2c K.W.-hr.)	1.3	cents per ton of stone

The electric power according to these estimates is cheaper when in operation at full capacity, but when running below this capacity there is a lower minimum charge that represents a lower cost, while with the steam plant the cost will be practically the same whether at full capacity or not. The electric power is also more convenient in distribution and handling through the plant. With this steady and abundant electric power, this area is especially favorable for location of industries, and there is the possibility of development of other water-powers along the streams and rivers of the area.

MINERAL SPRINGS.

A very considerable portion of the rain-water which falls upon the land sinks into the ground, and, as the rocks are more or less porous and traversed by joints, the water moves downward until it encounters an impervious rock or other obstruction. Much of this water usually issues at the surface in springs. Where the impervious layer, to which the water passes, comes to the surface at some point in outcrop, the water following that stratum will flow out as **surface springs,** the most common of springs. **Fissure springs** are found where the water comes from below through some deep fissure opening and may come from very considerable depths.

All springs are mineral springs and contain mineral matter in solution, the character of the mineral content depending on the nature of the rocks through which the water has passe on its journey to the surface. The amount of mineral matter in solution will depend on the temperature of the water, the presence of carbonic acid gas and vegetable or humous acids present, and the solubility of the rocks. The spring-water will contain a variety of minerals and some one mineral will usually be predominant and characteristic of the spring which is then named from its most prominent mineral or from the one supposed to give certain medicinal value. Saline springs are common salt waters, calcareous springs are high in lime, iron springs are called chalybeate, and sulphur, lithia, and other springs are found. When the spring-water is supposed to have valuable medicinal effects they are called medicinal springs.

In this eastern Panhandle area there are springs almost without number, some of which are large enough to supply a town and city water-supply, and by their volume of flow form streams of considerable size. Many of these springs have a pronounced mineral taste, others without taste are yet strong mineral springs. Iron springs and sulphur springs are numerous. Some of the well-known ones are near Bedington, east of Martinsburg, and seven miles southeast of Martinsburg, which are quite strong in sulphur. Iron springs are very common through the Devonian Shale country. Most of these sulphur and iron springs are not well known outside of the immediate district, but by development and advertisement might become very profitable investments. Their waters are equal to some of the widely known American medicinal springs. Nearly every farm in the area has good spring-water available. The city of Martinsburg secures its water-supply in high degree of purity from springs to the west of the city. Most of the small settlements are built around a town spring.

In only two localities in the area have the springs been famous over the country. One of these and the most noted is the Warm Springs at Berkeley Springs, which has been a famous resort since the days of Washington. From beneath the Warm Spring Ridge issue a series of warm springs with a natural temperature of 73° F. When the town was first chartered, the springs were reserved for the benefit of mankind, and they with the surrounding ground are owned by the State. This was a famous resort before the Civil War and afterward. There were large and commodious hotels later destroyed by fire. At the present time there is a spring pavilion, two large bath-houses, while in the town are good hotels and boarding-houses and many people seek this resort for pleasure and health.

The flow of water through these springs is estimated at 1,000 gallons per minute and the outflow forms a large volume of water in the Warm Spring Run. The water is also pumped through the town and is the municipal water-supply. An analysis of the water from these springs made by J. H. Dickson is given in the Pawpaw-Hancock Folio by Stose, as follows:

	Grains per Gallon.
Iron	0.506
Lime carbonate	9.577
Magnesium carbonate	1.951
Lime sulphate	1.098
Sodium chloride (common salt)	0.244
Silica	0.122
	13.498

While the percentage of mineral matter in this water is low compared with many springs, it is found to be very beneficial in certain disorders of the stomach and in some nervous disorders, and very helpful in many cases of rheumatism.

The other locality, which was a noted resort many years ago, but in more recent years appears to have fallen into the background, is at the Shannondale Spring, located five and a half miles from Charlestown in Jefferson County. There are three springs and the temperature of the water is 55° F. The three springs differ and are described as, a chalybeate or iron, a red sulphur, and a blue sulphur. These springs became well known in 1820 and a hotel and other buildings were erected. The water acted as a tonic and was regarded as especially beneficial in cases of dyspepsia, nervous diseases, and general debility.

Maury in the Resources of West Virginia (p. 326) gives an analysis of this water made by Dr. DeButts, of Baltimore, in 1821. One hundred grains of its solid contents on analysis yielded:

	Grains.
Carbonate of lime	10.5
Sulphate of lime	63.0
Sulphate of magnesia	23.5
Chloride of magnesia	1.0
Chloride of sodium	1.0
Sulphate of iron	0.3
Carbonate of iron	0.7

The quantity of sulphuretted hydrogen and carbonic acid gases was not determined.

OIL AND NATURAL GAS.

A common question in all parts of the country is whether certain tracts or farms are underlain with valuable deposits of oil and gas. Wildcat wells in various States have revealed such deposits and it would appear possible that other untested sections may in the future become valuable in these products.

In the eastern Panhandle there are a number of owners of lands who believe that below the surface these liquid and gaseous fuels exist probably in paying quantity, and it is a natural question whether the probabilities are in favor of drilling, and if not, why not. It is for these reasons that this subject is briefly treated in this Report.

For the past twenty-five years or more, the question of oil and gas exploration has been made the subject of most careful study both by the well drillers and by scientific experts, with the result that a fund of data has been collected on this subject, and the drilling of productive wells at the present time is not haphazard guesswork but has been reduced to a science founded on well-defined laws. No one can tell without error what lies hundreds of feet below the surface of the ground, so that it is not possible to state absolutely that there are no paying deposits of oil and gas under the lands of the eastern Panhandle area. The possibility of such deposits may exist here, but every known scientific, well drilling, and prospecting, fact is against this supposition, and it is most highly probable that no economically valuable oil or gas well or wells will ever be drilled in this area.

Many of the so-called surface indications for oil and gas cited in this area are of no value. Surface glistening iridescent scums on certain ponds or bodies of standing water are not oil scums, but iron and sulphur. The escaping gas in some of the pools is marsh gas resulting from the decay of vegetable matter below the surface of the water which, rising, breaks into bubbles which can be ignited. Oily residues may result on a small scale in a similar way so that a small vial may sometimes be filled with an oily water, but even this is rare.

There are owners of certain lands in this area who declare they have oil and gas and will listen to no argument to the contrary. Sometimes the proof is in the fact that some person from some of the large oil fields has examined the land and found the conditions similar and has located the oil and gas seepages similar to those in the large oil fields. Not all persons living in the larger oil fields are oil experts and oil seepages so often mentioned are seldom seen or noted in the large oil fields. The mere fact that the hills and valleys are similar to those in some oil fields has no bearing on the question as the deposits do not depend on hill or valley or their relation to each other.

Why then are not the conditions in this area favorable for oil and gas in the same way as in the producing territory? To answer this question involves a discussion of the necessary conditions for such accumulation and they are only four or five in number. There must first be a supply of oil or gas in the rocks below the surface, but this alone will not make a productive oil field, unless four other conditions are present.

1. There must be a **reservoir**; not necessarily in the form of a cavern, but in the form of a porous rock, in which the oil and gas are held in the interspaces of the rock. Such a rock is found in the Indiana and Ohio fields in the form of a porous magnesian limestone. In Pennsylvania, West Virginia, southeastern Ohio, Kansas, Oklahoma, etc., the reservoir is a sandstone. Such a porous sandstone is never empty, but it will contain water, oil or gas.

2. There must be a tight **cover** or the products will escape upward and be lost. This cover is usually in the form of a compact shale varying in thickness from a few feet to several hundred. When this cover is penetrated by the drill, the gas or oil released and under heavy pressure will reach the surface, in many cases raising the heavy drilling tools.

3. There must be **pressure** to force the gas or oil out of the rock. The rock pressure in gas wells forces the gas to the surface and out through the mains. It varies from less than a pound to over 1,500 pounds per square inch in some of the West Virginia gas wells when first drilled, but declines in time.

The cause of this rock pressure is a subject of dispute. In Ohio and Indiana there seemed to be an artesian water pressure back of the gas, the calculations of which by depth of well agreed closely with the gas pressure recorded on the gauge. In the high pressure wells of West Virginia, this theory fails. The only explanation offered for such wells is that the gas in the rocks is under compression, and when released by the drill, the expanding gas exerts its own pressure, increased by any water pressure that may be present back of it.

4. A fourth condition is **rock structure.** A fold in the rocks would give a favorable place for the accumulation of gas and oil, which without the fold might be distributed equally through the reservoir rock. The gas and oil fields of this State, Pennsylvania, Ohio, Kentucky, and others have been proved to be closely associated with folds in the rocks.

The **anticlinal theory** of oil and gas accumulation, first promulgated through practical application of its principles by I. C. White, has become a valuable working rule, and most oil men recognize its value in locating new wells and new fields. A careful review of this theory and its practical application are given in the oil and gas reports of the Survey.

In the eastern Panhandle area occur sandstones which are mostly compact and close-grained, but some of them could form an oil or gas reservoir. There is a large quantity of shales of great thickness which might act as a cover. The anticlines and synclines are on every hand, and with a rock pressure and gas and oil in the reservoir rocks, all the conditions listed above for accumulation would be present in abundance.

There is, however, in addition the greatly disturbed rock structure, sharp broken folds, fissures and fault-planes almost without limit. The rocks also stand vertical or highly inclined, so that the porous rock stratum that might act as a reservoir comes to the surface, and high pressure in the oil and gas would force these materials to the surface along this outcrop, if not through the various fissures that traverse the rock over the area of its distribution. These fissures and faults really act as so many wells which would long ago have drained any deposits that might have existed. If oil deposits ever did exist in this area, and there is no indication that they were present, the gaseous and more volatile liquid portions would have escaped and there would remain a deposit of heavy tarry or asphaltic material, as is to-day found along the Burning Springs Anticline in Ritchie County this State, which was formerly mined for asphalt or Grahamite for a number of years.

Oil and gas deposits are not known in broken strata of mountain regions, for there the conditions are all favorable for the escape of such products. There is therefore not the slightest encouragement to drill for oil or gas in this area, and the expenditure of money for this purpose would be wasteful.

PRECIOUS METALS.

In nearly all mountain areas, prospectors report the finding of gold and silver veins, or lead and copper, etc., and the mountains of this area are no exception. Silver and copper veins have been located in visionary minds for many, many years in these mountains, and the very age of the reports adds to their weight of authority in many cases, though the exact location of the vein is never found. There is always a loss of some of the essential data of the map of the veins.

The conditions of origin and accumulation of the precious and semiprecious metals is a complicated subject, but none of the essential conditions is present in these mountains for any of these deposits. There is one mineral, a sulphide of iron, known as pyrites, a bright yellow mineral, which has so often been taken for gold that it bears the name of "fool's gold". Its value in the quantity found in this State is nothing. There will be poor reward for the prospector of these metals in the mountains of the eastern Panhandle area. There is no copper, no lead, no zinc, of any commercial value, and the same is true of all the metals with the possible exception of iron.

APPENDIX "A".

LEVELS ABOVE MEAN TIDE IN THE EASTERN PANHANDLE AREA.

Baltimore and Ohio Railroad.

(Elevations to top of rail.)

		Feet.
Harpers Ferry Tunnel	Jefferson County	286.56
Engle Station	Jefferson County	379.59
Duffields	Jefferson County	482.06
Shenandoah Junction	Jefferson County	518.76
Kearneysville	Berkeley County	552.06
Van Clevesville	Berkeley County	475.27
Martinsburg	Berkeley County	427.74
Cherry Run Station	Morgan County	401.75
Sleepy Creek Station	Morgan County	401.22
Hancock	Morgan County	420.30
Round Top	Morgan County	427.15
Sir Johns Run	Morgan County	426.10
Great Cacapon	Morgan County	447.17
Woodmont	Morgan County	453.13
Lineburg	Morgan County	456.09
Orleans Road	Morgan County	505.00
Doe Gully	Morgan County	547.26
Magnolia	Morgan County	498.20
Pawpaw	Morgan County	529.83

Baltimore and Ohio Railroad, Shenandoah Valley Division.

Harpers Ferry	Jefferson County	287.03
Shenandoah	Jefferson County	287.83
Millville	Jefferson County	335.83
Halltown	Jefferson County	405.83
Charlestown	Jefferson County	515.83
Aldridge	Jefferson County	549.83
Baylor	Jefferson County	616.83
Summit Point	Jefferson County	625.83

Cumberland Valley Railroad.

		Feet.
Falling Waters	Berkeley County	364.00
Bedington	Berkeley County	383.00
Berkeley	Berkeley County	468.00
Martinsburg	Berkeley County	460.50
Tablers	Berkeley County	553.00
Darkesville	Berkeley County	553.90
Inwood	Berkeley County	568.90
Bunker Hill	Berkeley County	556.10
Ridgeway	Berkeley County	581.40

Norfolk and Western Railroad.

Rippon	Jefferson County	532
Charlestown	Jefferson County	530
Shenandoah Junction	Jefferson County	528
Shepherdstown	Jefferson County	418

ELEVATIONS ABOVE TIDE IN THE EASTERN PAN-HANDLE COUNTIES DETERMINED BY THE UNITED STATES GEOLOGICAL SURVEY.

WILLIAMSPORT QUADRANGLE.

Potomac River southwest along Cumberland Valley R. R. to Martinsburg.

	Feet.
Williamsport, 1.5 miles southwest of, near west end of railroad bridge No. 82-1, top of rail	380.5
Potomac River, surface of water under bridge No. 82-1, August 5, 1908	325
Williamsport, 2.3 miles southwest of, southwest corner of west bridge seat of railroad bridge No. 82-2, in top of; aluminum tablet stamped "363"	362.310
Williamsport, 3.4 miles southwest of, top of west foundation of water-tank and north end of; marked "G. S. B. M. 361"	361.14
Falling Waters, 500 feet east of, northeast corner of east bridge seat of railroad bridge No. 85; marked "G. S. B. M. 359"	358.80
Falling Waters, in front of station; top of rail	372.0
Falling Waters, 0.6 mile southwest of, in top of center of south head-wall of concrete box culvert under railroad at telephone-pole 85/31; aluminum tablet stamped "404"	403.973
Bedington, 1020 feet east of station, north side of track; in railroad concrete culvert; aluminum tablet stamped "387"	387.094
Bedington, in front of station, top of rail	392.3
Bedington, 270 feet west of station, south side of track; in top of railroad culvert; copper bolt (Pennsylvania R. R. bench mark)	391.806

	Feet.
Bedington, 0.3 mile south of, east side of north abutment of railroad bridge over creek, top of mud wall; marked "U. S. B. M. 396"	395.73
Berkeley, 1,500 feet north of station, overhead bridge in front face of east abutment; aluminum tablet stamped "471"	471.13
Berkeley, in front of station; top of rail	477.4

HANCOCK QUADRANGLE.

Berkeley Springs, west face of southwest corner-stone, Morgan County Courthouse; aluminum tablet stamped "612 C" (reported destroyed, courthouse torn down)	611.795
Stotlers Crossroads, 0.5 mile north of; at first ford of Sleepy Creek, ledge of rock east side of road, 0.25 mile north of north entrance to ford, in cleft of rock about 4 feet above roadway; aluminum tablet stamped "662 C"	661.964

McCoys Ferry up Back Creek.

Johnstown, 1.2 miles south of; on an outcrop of sandstone rock about 125 feet east of road forks and 2.5 miles west of Hedgesville; three small pines stand just south; chiseled square	561.34
Tomahawk, in northeast corner of foundation stone of W. W. Hedges's barn; aluminum tablet stamped "466 C"	466.543

PAWPAW QUADRANGLE.

Rock Gap, 700 feet west of Fearnow's house; 10 feet north of road at summit of gap, in rock; aluminum tablet stamped "761 C"	760.666
Great Cacapon, Md., on Lock 55 of Dam No. 6; U. S. C. & G. S. bench mark "C"	443.811
Fishers Ford, in large boulder, southeast corner of road, aluminum tablet stamped "MARYLAND 543 C"	543.188

ANTIETAM QUADRANGLE.

At Harpers Ferry.

Harpers Ferry, on northwest corner of south end of west abutment of road bridge near toll office; point marked "U. S. B. M. 279"	279.03
Harpers Ferry, in front face of post-office on south side of main entrance; aluminum tablet stamped "Adj. 275"	274.416

BERRYVILLE QUADRANGLE.

From Summit Point east to Kabletown, thence northeast to Keys Ford, Shenandoah River.

	Feet.
Summit Point, northeast corner of railroad crossing, in base of sign-post; spike marked "U. S. B. M. 620"	620.07
Summit Point, 1.4 miles south of, west side of road, in telephone pole; spike, marked "U. S. B. M. 617"	617.27
Summit Point, 2.7 miles southeast of, south side of road, in ledge; bronze tablet stamped "620"	620.158
Summit Point, 3.8 miles southeast of, north side of road, in telephone-pole; spike, marked "U. S. B. M. 548"	548.37
Rippon; top of west rail at road crossing, marked "U. S. 521"	520.6
Rippon, southeast corner of roads at post-office, in telephone-pole; spike, marked "U. S. B. M. 537"	536.68
Rippon, 2.2 miles east of, 100 feet north of forks of roads, east side of road; in ledge; bronze tablet stamped "509"	508.791
Kabletown, at forks of roads, at Kabletown Schoolhouse, in telephone-pole; spike, marked "U. S. B. M. 478"	477.64
Kabletown, 1 2 miles north of, east side of road, in culvert; bronze tablet stamped "433"	432.811
Kabletown, 2.3 miles north of, east side of north end of bridge over Evitts Run; painted bolt-head, marked "U. S. B. M. 404"	403.74
Mechanicstown, opposite sign-post "Kabletown," in telephone-pole; spike, marked "U. S. B. M. 446"	446.49
Mechanicstown, 0.9 mile southeast of, in northeast corner of concrete arch over Evitts Run; bronze tablet stamped "352"	352.07
Mannings Ferry; water surface of Shenandoah River, July 31, 1914, 11:30 a. m	330.6
Mannings Ferry, 0.7 mile east of, south side of road, in root of tree; copper nail with washer, stamped "U. S. G. S., W. Va. B. M.," marked "U. S. B. M. 336"	336.22
Mannings Ferry, 1.8 miles east of, east side of road, in root of stump; copper nail with washer, stamped "U. S. G. S., W. Va., B. M.," marked "U. S. B. M. 413"	413.16

GERRARDSTOWN QUADRANGLE.

From Tablers southwest along Cumberland Valley R. R. to Bunker Hill, thence southeast along highway to Middleway.

Tablers, northwest corner of grade crossing, in telephone-pole; spike, marked "U. S. B. M. 560"	560.222
Tablers, front of station; top of west rail	560.8
Tablers, 0.9 mile south of, 200 feet south of road crossing, east side of track, in ledge; bronze tablet stamped "562"	561.635
Darkesville, front of station; top of east rail	562.0
Darkesville, northwest corner of road crossing, in root of tree; copper nail with washer stamped "U. S. G. S. B. M. W. Va.," marked "U. S. B. M. 560"	560.494

	Feet.
Inwood, front of station; top of west rail	575.7
Inwood, northeast corner of base of signal-post; painted bolt-head, marked "U. S. B. M. 576"	575.616
Inwood, 0.3 mile east of, northwest corner of roads at toll-gate, in ledge; bronze tablet stamped "569 Prim. Trav. Sta. No. 6, 1914"	568.810
Inwood, 1.5 miles south of, east side of track, on ledge; chiseled square, marked "U. S. B. M. 580"	579.83
Bunker Hill, 25 feet northeast of road crossing, in base of warning sign-post; spike, marked "U. S. B. M. 565"	564.93
Bunker Hill, 2 miles east of, south side of road, in cement culvert; bronze tablet stamped "538"	538.515
Bunker Hill, 2.8 miles east of, 60 feet west of Fairview Schoolhouse, in root of tree; copper nail with washer, stamped "U. S. G. S. W. Va. B. M.," marked "U. S. B. M. 568"	567.791
Bunker Hill, 4.3 miles east of, north end of east abutment of bridge over Opequon Creek; chiseled square, marked "U. S. B. M. 443"	443.322

From Inwood northwest to Ganotown, thence northeast to Jones Springs.

Inwood, 0.3 mile east of, in northwest corner of cross-roads, 45 feet northwest of toll-gate, in limestone ledge; bronze tablet stamped "569"	568.810
Inwood, 1.1 miles west of, 180 feet west of road fork, 15 feet south of highway, on limestone ledge; chiseled square, marked "652 B. M"	651.98
Inwood, 1.8 miles west of, in southeast corner of cross-roads, on limestone ledge; chiseled square, marked "631 B. M".	631.19
Gerrardstown, in concrete porch floor of D. S Griffith's store, 3 feet east of main entrance; bronze tablet stamped "676"	676.413
Gerrardstown, 1.3 miles west of, 14 feet south of highway, in root of pine tree; nail marked "841 B. M."	840.958
Gerrardstown, 1.9 miles northwest of, summit of Little North Mountain, in southwest corner of cross-roads on sandstone ledge; chiseled square, marked "1083 B. M."	1082.75
Ganotown, 2.1 miles east of, in northwest corner of road fork, in root of red-oak tree; nail, marked "648.6 B M."	648.60
Ganotown, 1.6 miles east of, 230 feet east of road fork, 8 feet north of highway, in sandstone ledge; bronze tablet stamped "610"	610.380
Ganotown, 0.2 mile east of, 17 feet north of highway; nail in base of cedar tree marked "513 B. M."	512.70
Ganotown, at road fork, on top of property corner-stone; painted square marked "545 B. M."	545.11
Ganotown, 0 8 mile north of. northeast corner of foundation wall of United Brethren Church, in north face; bronze tablet stamped "577"	577.168
Shanghai, 1.3 miles south of, in southeast corner of road fork; nail in root of white-oak tree, marked "523 B. M."	523.14
Shanghai, northeast corner of cross-roads, 4 feet north of southwest corner of store building, in top of concrete foundation; bronze tablet stamped "529"	529.156
Shanghai, 1.1 miles north of, in northeast corner of road fork; nail in root of large oak tree, marked "490 B. M."	489.89

Feet.

Shanghai, 2.5 miles north of, south end of west abutment to highway bridge over small stream; chiseled square, marked "527 B. M." 527.133

Jones Springs, 0.4 mile south of, in top of east side of concrete porch floor of Jones Springs School; bronze tablet stamped "586" 585.900

Jones Springs, 0.7 mile north of, in southwest corner of road fork; chiseled square on sandstone ledge, marked "725 B. M." 725.20

From Shanghai west to Ungers Store, thence north to Oakland.

Shanghai, 1.4 miles west of, 8 feet north of highway; nail in base of telephone-pole, marked "765 B. M" 764.93

Shanghai, 2.4 miles west of, 4 feet north of highway; chiseled square on sandstone ledge, marked "1112 B. M." 1112.44

Shanghai, 3.5 miles west of, on summit, 4 feet south of highway, in sandstone ledge; bronze tablet stamped "1584"..1583.888

Shanghai, 4.5 miles west of, 12 feet north of highway; nail in base of poplar tree, marked "1832 B. M." 1832.01

Ungers Store, 4 miles east of, summit of Sleepy Creek Mountain, 4 feet south of highway; chiseled square on sandstone ledge, marked "1841 B. M." 1841.00

Ungers Store, 2.8 miles east of, 20 feet south of highway, in large sandstone boulder; bronze tablet stamped "1265"...1264.604

Ungers Store, 1.4 miles east of, 130 feet east of school building, 30 feet west of road fork; nail in root of black-oak tree, marked "1054 B. M." 1054.07

Ungers Store, 150 feet west of, 12 feet north of highway; nail in root of cherry tree, marked "B. M." 905.22

Ungers Store, 370 feet west of, in southwest corner of road fork; nail in root of large oak tree, marked "886 B. M.".. 886.16

Ungers Store, 0.7 mile west of, 200 feet east of cross-roads, 20 feet north of highway, in sandstone ledge; bronze tablet stamped "850" 849.551

Oakland, 1.8 miles south of, 30 feet south of stream crossing, 8 feet west of highway; nail in base of oak tree, marked "781 B. M." 780.618

Oakland, 0.9 mile south of, at road fork, 13 feet west of highway; nail in base of telephone-pole, marked "768 B. M.".. 768.017

Oakland, in center of concrete approach to S. E. Shockey's residence; bronze tablet stamped "764" 763.694

Oakland, 1.5 miles north of, in southwest corner of road fork; nail in base of mail-box post, marked "707 B. M." 707.00

MARTINSBURG QUADRANGLE.

From Martinsburg Northeast along Cumberland Valley R. R. to Berkeley, thence East and South to Shepherdstown.

Martinsburg, at King Street entrance to Berkeley County Courthouse, eastern end of first step up from sidewalk; tablet stamped "457.7" 456.692

	Feet.
Martinsburg, about 0.2 mile west of station, about 280 feet east of milepost "Baltimore 100 miles," in middle of north coping of an arch; copper bolt (Baltimore & Ohio R. R. Bench Mark 75)	432.913
Martinsburg, 1.5 miles northeast of, 10 feet east of Cumberland Valley R. R., on limestone ledge; chiseled square, marked "487 B. M."	487.019
Martinsburg, 2.5 miles northeast of, 225 feet north of milepost 91, 27 feet east of Cumberland Valley R. R., on limestone ledge; chiseled square, marked "487.4 B. M."	487.463
Berkeley, opposite station; top of rail	477.265
Berkeley, 1,500 feet north of station, overhead bridge, in front face of east abutment; aluminum tablet stamped "471"	471.130
Berkeley, 0.3 mile northeast of, 45 feet north of overgrade bridge, 10 feet west of Cumberland Valley R. R., in limestone ledge; bronze tablet stamped "Prim. Trav. Sta. No. 1, 1914"	470.096
Berkeley, 1.9 miles southeast of, 300 feet southeast of dwelling, 15 feet south of highway, on limestone ledge; chiseled square, marked "394.5 B. M."	394.568
Berkeley, 3.1 miles southeast of, 25 feet south of road fork, on limestone ledge; chiseled square, marked "472 B. M."	472.058
Berkeley, 4.4 miles east of, 150 feet east of Herman Lam residence, at right-angled turn in highway, 15 feet east of highway, in limestone ledge; bronze tablet stamped "468"	468.498
Scrabble, 1.6 miles west of, 25 feet west of road fork, 50 feet east of road fork, 20 feet north of highway, on limestone ledge; chiseled square, marked "434 B. M."	434.103
Scrabble, 0.5 mile west of, 50 feet west of road fork, 7 feet north of highway, on limestone ledge; chiseled square, marked "394.8 B. M."	394.925
Scrabble, 50 feet east of highway bridge over Rockymarsh Run, 14 feet south of highway; bronze tablet stamped "Prim. Trav. Sta. No. 2, 367, 1914"	366.834
Scrabble, 1.2 miles southeast of, 12 feet south of highway, in limestone ledge; chiseled square, marked "407.9 B. M."	407.996
Shepherdstown, 3.4 miles north of, 30 feet north of road fork, in top of stone retaining wall; chiseled square, marked "422.4 B. M."	422.572
Shepherdstown, 2.1 miles north of, 70 feet north of road fork, 12 feet west of highway, in limestone ledge; bronze tablet stamped "462"	461.824
Shepherdstown, 1.1 miles north of, 125 feet west of dwelling, 10 feet south of highway, in limestone ledge; chiseled square, marked "424.4 B. M."	424.556
Shepherdstown, northwest corner of German and Duke Streets, in center of top of manhole guardstone; chiseled square	443.422
Shepherdstown, in front face of post-office, 3 feet east of main entrance; aluminum tablet, stamped "Adj. 406"	405.451

From Shepherdstown southwest via Kearneysville to point 3.4 miles south of Middleway.

Shepherdstown, 1 mile southwest of, 60 feet west of northwest corner of fair grounds, 12 feet south of highway, in limestone ledge; chiseled square, marked "467.2 B. M."	467.348

Feet.

Shepherdstown, 1.9 miles southwest of, 35 feet south of Drake monument, on limestone outcrop; chiseled square, marked "545.8 B. M." 545.982

Shepherdstown, 2.7 miles southwest of, 14 feet south of highway, 500 feet southwest of road fork, in limestone outcrop; bronze tablet stamped "515" 515.224

Kearneysville, 1.7 miles northeast of, in southeast corner of cross-roads; chiseled square on limestone ledge marked "517.0 B. M." 517.217

Kearneysville, 0.6 mile northeast of, at road fork, 18 feet south of highway, on limestone ledge; chiseled square, marked "515.6 B. M." 515.806

Kearneysville, about 200 feet west of railroad crossing, south side of road, in ledge; bronze tablet stamped "P. Trav. Sta. No. 8, 1914, 548" 548.164

Kearneysville, about 0.3 mile south of, about 75 feet east of milepost Balto. 92, in rock on north side of tracks; copper bolt (B. & O. b. m. No. 67) 564.415

Leetown, 2.4 miles north of, east side of road, in root of tree; copper nail with washer, stamped "U. S. G. S. W. Va. B. M." marked "U. S. B. M 523" 522.94

Leetown, 1 mile north of, in triangle made by forks of roads, on ledge; chiseled square, marked "U. S. B. M. 495" 494.60

Leetown, north side of doorway of M. E. Church South, in cement walk; bronze tablet stamped "503" 502.910

Middleway, 1 8 miles northeast of, east side of road, at summit of hill, in telephone-pole; spike marked "U. S. B. M. 587" 587.41

Middleway, 1 1 miles north of, east side of road, in telephone-pole; spike marked "U. S. B. M. 508" 508.20

Middleway, northeast corner of vacant building owned by Mrs. W. H. Gilbert; bronze tablet stamped "500" 500.014

Middleway, 1.2 miles south of, west side of road, on ledge; chiseled square, marked "U. S. B. M. 540" 540.518

Middleway, 2.1 miles south of, east side of road, in stump; copper nail with washer, stamped "U. S. G. S. W. Va. B. M.", marked "U. S. B M. 562" 562.24

Middleway, 3.4 miles south of, 150 feet south of forks of roads, east side of road, in ledge; bronze tablet stamped "585" .. 584.634

From Shepherdstown southeast to point 1.8 miles west of Harpers Ferry.

Shepherdstown, 1 mile south of, in south vertex of triangle at road junction, in top of property corner-stone; chiseled square, marked "462.4 B. M." 462.62

Shepherdstown, 2.1 miles southeast of, at cross-roads, 7 feet north of concrete monument "4" on limestone ledge; chiseled square, marked "472.5 B. M." 472.66

Shepherdstown, 3.1 miles southeast of, 100 feet west of Lucas Creek, 14 feet north of highway, in limestone ledge; bronze tablet, stamped "372" 371.865

Shepherdstown, 4 miles southeast of, 10 feet north of highway, on limestone ledge; chiseled square, marked "439 B M." .. 439.21

Harpers Ferry, 5 miles north of, about 400 feet west of Potomac River, 12 feet east of highway, in limestone ledge; bronze tablet, stamped "318" 317.980

	Feet.
Harpers Ferry, 4.8 miles north of, 400 feet north of dwelling, 8 feet west of highway, on limestone ledge; chiseled square, marked "379.7 B. M."	379.945
Harpers Ferry, 3.9 miles north of, 5 feet east of highway, on limestone ledge; chiseled square, marked "381.9 B. M.".	382.18
Harpers Ferry, 3.3 miles north of, 50 feet south of road fork, 16 feet east of road, in limestone ledge; bronze tablet stamped "431"	431.141
Harpers Ferry, 2.2 miles northwest of, 12 feet west of highway, on limestone ledge; chiseled square, marked "400.6 B. M."	400.90
Harpers Ferry, 1.8 miles west of, northeast corner of Baltimore & Ohio concrete overgrade bridge; painted square, marked "324.2"	324.502

From Keys Ford northeast to Harpers Ferry.

Keys Ford; water surface of Shenandoah River, August 1, 1914, 9:20 a. m	298.0
Keys Ferry; water surface of Shenandoah River, August 1, 1914, 9:45 a. m	295.2
Keys Ferry, 50 feet west of landing, east side of road, in ledge; bronze tablet stamped "301"	301.214
Harpers Ferry Lime Co.'s ferry; water surface of Shenandoah River, August 1, 1914, 11 a. m	294.5
Millville, in front of station; top of south rail	334.3
Millville, opposite station, north side of road, in root of tree; copper nail with washer stamped "U. S. G. S. W. Va. B. M.", marked "U. S. B. M. 338"	338.286
Millville, 1 mile northeast of, 50 feet north of milepost "H. F. 3 S. J. 48", west side of track, in rail rest; copper nail with washer, stamped "U. S. G. S. W. Va. B. M.", marked "U. S. B. M. 310"	309.76
Millville, 2 miles northeast of, 100 feet north of milepost "H F. 2 S. J. 49", west side of track, in ledge; bronze tablet stamped "298"	297.713
Millville, 3 1 miles northeast of, west side of north end of trestle; painted bolt-head, marked "U. S. B. M. 283"	283.26

From Martinsburg southwest along Cumberland Valley R. R. 3.7 miles (part of circuit; see continuation in Gerrardstown Quadrangle.)

Martinsburg, about 0.2 mile west of station, about 280 feet east of milepost "Balto. 100", in middle of north coping of an arch; copper bolt (B. & O. b. m. No. 75)	432.913
Martinsburg, 60 feet north of Cumberland Valley R. R. depot, 10 feet west of tracks, in root of tree; copper nail with washer, stamped "U. S. G. S. W. Va. B. M.", marked "U. S. B. M. 466"	466.419
Martinsburg, in front of Cumberland Valley R. R. depot; top of east rail	467.4

Feet.

Martinsburg, 1 mile southwest of, east side of track, in telephone-pole; spike marked "U. S. B. M. 498" 497.79

Martinsburg, 2.2 miles southwest of, about 600 feet north of milepost 96, east side of track, in ledge; bronze tablet, stamped "532" 531.591

Martinsburg, 3.7 miles southwest of, 15 feet south of private road crossing, east side of track, on ledge; chiseled square, marked "U. S. B. M. 535" 535.00

PRECISE LEVELING BY THE UNITED STATES COAST AND GEODETIC SURVEY AND THE BALTIMORE AND OHIO RAILROAD.

Bulletin 632 of the U. S. Geological Survey gives the following levels in the eastern Panhandle area of West Virginia, with the following introductory explanation:

"The following descriptions and elevations are extracted from reports of the Coast and Geodetic Survey and are here republished by permission of the Superintendent of that bureau. The bench marks were established by the Coast and Geodetic Survey and by the Baltimore & Ohio Railroad Co., and were included in the 1907 adjustment by the Coast and Geodetic Survey. The elevations were not changed by the 1912 adjustment and are not likely to be changed by any future adjustment.

"For convenient reference, as results in Bulletin 399 are based on the 1903 adjustment, the elevations of bench marks established previous to 1903 are given by both the 1903 and 1907 adjustments."

ANTIETAM QUADRANGLE.

Bench marks established at Harpers Ferry.

Feet.

Harpers Ferry, on north side of tracks, almost directly across from Harpers Ferry signal-tower, in capstone of north wing of west abutment of bridge; copper bolt (B. & O. bench mark 56A) 285.432
(1903 adjusted value = 285.628).

Harpers Ferry, about 0.5 mile west of, 180 feet west of milepost "Baltimore 82 miles" in native rock on south side of tracks; copper bolt (B. & O. R. R. bench mark 57) 290.818
(1903 adjusted value = 291.014).

MARTINSBURG QUADRANGLE.

Harpers Ferry northwest along Baltimore and Ohio R. R. to Martinsburg.

Feet.

Engle, 1.8 miles east of, about 70 feet east of milepost "Baltimore 83 miles" in native rock on north side of tracks, about 8 feet from tracks; copper bolt (B. & O. bench mark 58) 309.940
(1903 adjusted value = 310.139).

Engle, about 0.7 mile east of, on south side of tracks, in middle of coping of bridge 45; copper bolt (B. & O. bench mark 59) 354.745
(1903 adjusted value = 354.946).

Engle, about 0.2 mile west of, about 30 feet west of milepost "Baltimore 85 miles," in native rock on south side of tracks; copper bolt (B. & O. bench mark 60) 386.541
(1903 adjusted value = 386.744).

Engle, about 1.2 miles west of, about 600 feet east of milepost "Baltimore 86 miles," in native rock on north side of tracks; copper bolt (B. & O. bench mark 61) 411.226
(1903 adjusted value = 411.433).

Duffields, about 1 mile east of, in south end of east wall of culvert 45G; copper bolt (B. & O. bench mark 62) 440.895
(1903 adjusted value = 441.103).

Duffields, about 50 feet east of milepost "Baltimore 88 miles," in west end of north coping of culvert 45L; copper bolt (B. & O. bench mark 63) 484.271
(1903 adjusted value = 484.479).

Shenandoah Junction, about 0.3 mile west of, about 400 feet west of milepost "Baltimore 89 miles," in native rock on south side of tracks; copper bolt (B. & O. bench mark 64) 530.635
(1903 adjusted value = 530.848).

Shenandoah Junction, about 1.5 miles west of, about 500 feet west of milepost "Baltimore 90 miles," opposite telegraph-pole 90—4 in a ledge of rock on north side of tracks; copper bolt (B. & O. bench mark 65) 560.324
(1903 adjusted value = 560.539).

Hobbs, near, about 200 feet west of milepost "Baltimore 91 miles," in north end of west abutment of bridge 45; copper bolt (B. & O. bench mark 66) 583.929
(1903 adjusted value = 584.145).

Kearneysville, about 0.3 mile south of, about 75 feet east of milepost "Baltimore 92 miles," in rock on north side of tracks; copper bolt (B. & O. bench mark 67) 564.415
(1903 adjusted value = 564.635).

Kearneysville, about 1.2 miles north of, opposite milepost "Baltimore 93 miles," section of rail set vertically in ground (B. & O. bench mark 68) 528.359
(1903 adjusted value = 528.580).

Van Clevesville, about 1.2 miles southeast of, opposite milepost "Baltimore 94 miles," section of rail set vertically in ground (B. & O. bench mark 69) 497.545
(1903 adjusted value = 497.767).

Feet.

Van Clevesville, about 0.2 mile south of, almost directly behind milepost "Baltimore 95 miles," in a large rock on north side of tracks; copper bolt (B. & O. bench mark 70) 478.086
(1903 adjusted value = 478.311).

Van Clevesville, about 0.8 mile northwest of, 250 feet west of milepost "Baltimore 96 miles," in rock on south side of tracks; copper bolt (B. & O. bench mark 71)........... 450.599
(1903 adjusted value = 450.827).

Van Clevesville, about 1.8 miles northwest of, about 500 feet west of milepost "Baltimore 97 miles," in west end of south coping of a culvert; copper bolt (B. & O. bench mark 72)... 403.933
(1903 adjusted value = 404.164).

Opequon, near, about 600 feet east of milepost "Baltimore 98 miles," on north side of tracks, on west end of coping of culvert at telegraph-pole 97/34; copper bolt (B. & O. bench mark 73).................................... 384.061
(1903 adjusted value = 384.291).

Martinsburg, 0.7 mile east of, 240 feet west of milepost "Baltimore 99 miles" in middle of north coping of bridge 49.2; copper bolt (B. & O. bench mark 74)................. 399.333
(1903 adjusted value = 399.568).

Martinsburg, about 0.2 mile west of station, about 280 feet east of milepost "Baltimore 100 miles," in middle bench of north coping of an arch; copper bolt (B. & O. bench mark 75) 432.911
(1903 adjusted value = 433.147).

Martinsburg, about 1.5 miles northwest of, opposite milepost "Baltimore 101 miles," section of rail set vertically in ground (B. & O. bench mark 76)...................... 469.661
(1903 adjusted value = 469.899).

WILLIAMSPORT QUADRANGLE.

Martinsburg north along Baltimore and Ohio R. R. to Back Creek.

Martinsburg, about 2.5 miles northwest of, about 800 feet west of milepost "Baltimore 102 miles," in native rock on the north side of tracks; copper bolt (B. & O. bench mark 77) 490.258
(1903 adjusted value = 490.500).

Tabb, near, about 40 feet east of milepost "Baltimore 103 miles," in native rock; copper bolt (B. & O. bench mark 78) 527.079
(1903 adjusted value = 527.323).

Tabb, near, about 200 feet west of milepost "Baltimore 104 miles," in a large rock on north side of tracks; copper bolt (B. & O. bench mark 79)......................... 522.637
(1903 adjusted value = 522.883).

Tabb, about 1.2 miles northwest of, opposite milepost "Baltimore 105 miles;" section of rail set vertically in ground (B. & O. bench mark 80).............................. 518.103
(1903 adjusted value = 518.349).

Feet.

North Mountain, about 1.2 miles southeast of, about 500 feet west of milepost "Baltimore 106 miles," between tracks in the bridge seat of the east abutment of bridge 52; copper bolt (B. & O. bench mark 81) 506.938
(1903 adjusted value = 507.188).

North Mountain, about 0.2 mile south of station, 850 feet west of milepost "Baltimore 107 miles," between tracks in bridge seat of east abutment of bridge 52½; copper bolt (B. & O. bench mark 82) 527.896
(1903 adjusted value = 528.149).

North Mountain, about 0.5 mile north of, opposite milepost "Baltimore 108 miles," section of rail set vertically in ground (B. & O. bench mark 83) 528.471
(1903 adjusted value =528.726).

North Mountain, about 1.5 miles northwest of, about 100 feet east of milepost "Baltimore 109 miles," section of rail set vertically in ground (B. & O. bench mark 84) 504.116
(1903 adjusted value = 504.374).

Back Creek, near, opposite milepost "Baltimore 110 miles;" section of rail set vertically in ground (B. & O. bench mark 85) 461.840
(1903 adjusted value = 462.700).

HANCOCK QUADRANGLE.

Back Creek northwest along Baltimore and Ohio R. R. to Sir Johns Run.

Back Creek, west of, in north end of the west abutment of bridge 53; copper bolt (B. & O. bench mark 86) 426.400
(1903 adjusted value = 426.662).

Cherry Run, about 1.5 miles southeast of, opposite milepost "Baltimore 112 miles;" section of rail set vertically in ground between tracks (B. & O. bench mark 87) 391.636
(1903 adjusted value = 391.900).

Cherry Run, about 0.6 mile east of, in south end of bridge seat of west abutment of bridge 54; copper bolt (B. & O. bench mark 88) 384.835
(1903 adjusted value = 385.101).

Cherry Run, about 0.5 mile west of, opposite milepost "Baltimore 114 miles;" section of rail set vertically in ground (B. & O bench mark 89) 396.597
(1903 adjusted value = 396.865).

Miller, near, opposite milepost "Baltimore 115 miles;" section of rail set vertically in ground (B. & O. bench mark 90) 404.336
(1903 adjusted value = 404.608).

Miller, near, opposite milepost "Baltimore 116 miles;" section of rail set vertically in ground (B. & O. bench mark 91).. 396.302
(1903 adjusted value = 396.575).

Sleepy Creek, about 0.4 mile east of, opposite milepost "Baltimore 117 miles;" section of rail set vertically in ground (B. & O. bench mark 92) 399.186
(1903 adjusted value = 399.461).

Sleepy Creek, between tracks in bridge seat of east abutment of bridge 55; copper bolt (B. & O. bench mark 92A)......395.560
(1903 adjusted value = 395.836).

Feet.

Sleepy Creek, 0.5 mile west of, opposite milepost "Baltimore 118 miles;" section of rail set vertically in ground (B. & O. bench mark 93) 401.249
(1903 adjusted value = 401.527).

Sleepy Creek, about 1.5 miles west of, opposite milepost "Baltimore 119 miles"; section of rail set vertically in ground (B. & O. bench mark 94) 405.783
(1903 adjusted value = 406.061).

Sleepy Creek, about 2.5 miles west of, opposite milepost "Baltimore 120 miles;" section of rail set vertically in ground (B. & O. bench mark 95) 406.948
(1903 adjusted value = 407.229).

Hancock, about 2 miles east of, opposite milepost "Baltimore 121 miles;" section of rail set vertically in ground (B. & O. bench mark 96) 405.058
(1903 adjusted value = 405.341).

Hancock, about 1 mile east of, opposite milepost "Baltimore 122 miles;" section of rail set vertically in ground (B. & O. bench mark 97) 409.081
(1903 adjusted value = 409.366).

Hancock, west end of north coping of bridge 56; copper bolt (B. & O. bench mark 97A) 417.388
(1903 adjusted value = 417.675).

Hancock, about 0.2 mile west of, opposite milepost "Baltimore 123 miles;" section of rail set vertically in ground (B. & O. bench mark 98) 418.746
(1903 adjusted value = 419.034).

Hancock, about 1.2 miles southwest of, opposite milepost "Baltimore 124 miles;" copper bolt set vertically in ground (B. & O. bench mark 99) 417.217
(1903 adjusted value = 417.507).

Round Top, about 1 mile northeast of, opposite milepost "Baltimore 125 miles;" section of rail set vertically in ground (B. & O. bench mark 100) 415.603
(1903 adjusted value = 415.896).

Round Top, opposite milepost "Baltimore 126 miles;" section of rail set vertically in ground (B. & O. bench mark 101) 426.630
(1903 adjusted value = 426.927).

Round Top, about 1 mile southeast of, 150 feet east of milepost "Baltimore 127 miles;" in a rock outcrop on the north side of the tracks; copper bolt (B. & O. bench mark 102) 426.371
(1903 adjusted value = 426.670).

Sir Johns Run, about 0 5 mile north of, opposite milepost "Baltimore 128 miles;" section of rail set vertically in ground (B. & O. bench mark 103) 424.943
(1903 adjusted value = 425.247).

Sir Johns Run, about 0.5 mile south of, 20 feet west of telegraph-pole 123/38, in native rock on south side of tracks; copper bolt (B. & O. bench mark 104) 426.699
(1903 adjusted value = 427.006).

Sir Johns Run, about 0.5 mile south of, about 400 feet west of milepost "Baltimore 130 miles;" set in culvert coping on south side of tracks; copper bolt (B. & O. bench mark 105) 426.600
(1903 adjusted value = 426.909).

PAWPAW QUADRANGLE.

Great Cacapon west along Baltimore and Ohio R. R. to Little Cacapon.

Feet.

Great Cacapon, 1 mile east of, about 200 feet east of milepost "Baltimore 131 miles," in large rock on north side of track; copper bolt (B. & O. bench mark 106)............ 436.334
(1903 adjusted value = 436.648).

Great Cacapon, near, between tracks in bridge seat of east abutment of bridge 57 across Great Cacapon River; copper bolt (B. & O. bench mark 107).......................... 435.613
(1903 adjusted value = 435.929).

Great Cacapon, about 1 mile west of, opposite milepost "Baltimore 133 miles;" section of rail set vertically in ground (B. & O. bench mark 108)........................... 452.978
(1903 adjusted value = 453.298).

Woodmont, 0.3 mile west of, opposite milepost "Baltimore 134 miles;" section of rail set vertically in ground (B. & O. bench mark 109)................................... 450.435
(1903 adjusted value = 450.759).

Lineburg, about 0.8 mile east of, opposite telegraph-pole 135/4; copper bolt in rock on south side of tracks (B. & O. bench mark 110).................................454.169
(1903 adjusted value = 454.495).

Lineburg, about 0.2 mile west of, opposite milepost "Baltimore 136 miles;" section of rail set vertically in ground (B. & O. bench mark 111)................................ 458.214
(1903 adjusted value = 458.541).

Lineburg, about 1.2 miles south of, 25 feet east of milepost "Baltimore 137 miles;" in a rock on south side of tracks; copper bolt (B. & O. bench mark 112).................. 468.729
(1903 adjusted value = 469.061).

Orleans Road, about 0.8 mile east of, opposite milepost "Baltimore 138 miles;" section of rail set vertically in ground (B. & O. bench mark 113)............................ 487.850
(1903 adjusted value = 488.186).

Orleans Road, about 0.3 mile south of, opposite milepost "Baltimore 139 miles;" section of rail set vertically in ground (B. & O. bench mark 114)............................ 504.277
(1903 adjusted value = 504.613).

Rockwell Run, near, 500 feet beyond milepost "Baltimore 140 miles;" in rock on south side of tracks; copper bolt (B. & O. bench mark 115).............................. 523.004
(1903 adjusted value = 523.343).

Doe Gully, opposite milepost "Baltimore 141 miles;" section of rail set vertically in ground (B. & O. bench mark 116)... 546.652
(1903 adjusted value = 546.995).

Doe Gully, about 1 mile south of, opposite milepost "Baltimore 142 miles;" section of rail set vertically in ground (B. & O. bench mark 117)................................ 544.057
(1903 adjusted value = 544.404).

Hansrote, 1 mile northeast of, directly opposite milepost "Baltimore 143 miles;" in rock on south side of tracks; copper bolt (B. & O. bench mark 118)....................... 520.465
(1903 adjusted value = 520.815).

Feet.

Hansrote, near, opposite milepost "Baltimore 144 miles;" section of rail set vertically in ground (B. & O. bench mark 119) 494.218
(1903 adjusted value = 494.572).

Hansrote, about 1 mile west of, opposite milepost "Baltimore 145 miles;" section of rail set vertically in ground (B. & O. bench mark 120).................................... 497.886
(1903 adjusted value = 498.242).

Baird, near, opposite milepost "Baltimore 146 miles;" section of rail set vertically in ground (B & O. bench mark 121) 497.643
(1903 adjusted value = 498.003).

Baird, about 1 mile southwest of, opposite milepost "Baltimore 147 miles;" section of rail set vertically in ground (B. & O. bench mark 122).................................... 489.894
(1903 adjusted value = 490.256).

Magnolia, about 1 mile northwest of, opposite milepost "Baltimore 148 miles;" section of rail set vertically in ground (B. & O. bench mark 123).............................. 494.074
(1903 adjusted value = 494.440).

Magnolia, about 0.2 mile east of, 500 feet beyond milepost "Baltimore 149 miles;" on south side of tracks in east end of coping of bridge 47D; copper bolt (B. & O. bench mark 124) 497.630
(1903 adjusted value = 498.004).

Magnolia, about 1 mile southeast of, opposite milepost "Baltimore 150 miles;" section of rail set vertically in ground (B. & O. bench mark 125)..............................502.076
(1903 adjusted value = 502.447).

Magnolia, about 2 miles south of, opposite milepost "Baltimore 151 miles;" copper bolt in rock (B. & O. bench mark 126) 511.521
(1903 adjusted value = 511.896).

Pawpaw, about 1 mile north of, opposite milepost "Baltimore 152 miles;" in a rock on south side of tracks; copper bolt (B. & O. bench mark 127).............................. 516.226
(1903 adjusted value = 516.603).

Pawpaw, about 0.8 mile north of, opposite milepost "Baltimore 153 miles;" section of rail set vertically in ground (B. & O. bench mark 128).................................... 526.652
(1903 adjusted value = 527.034).

Pawpaw, about 0 2 mile south of, opposite milepost "Baltimore 154 miles;" section of rail set vertically in ground (B. & O. bench mark 129).................................... 534.067
(1903 adjusted value = 534.454).

Pawpaw, 1.5 miles south of, opposite milepost "Baltimore 155 miles;" section of rail set vertically in ground (B. & O. bench mark 130).................................... 532.072
(1903 adjusted value = 532.459).

Little Cacapon, about 1 mile east of, about 500 feet east of milepost "Baltimore 156 miles;" on south side of tracks in middle stone of coping of culvert; copper bolt (B. & O. bench mark 131).................................... 528.851
(1903 adjusted value = 529.243).

APPENDIX "B".

LOCATION OF TRUE MERIDIAN LINES.

In the summer of 1898, true north and south meridian lines were established by the West Virginia Geological Survey in cooperation with the U. S. Geological Survey. These lines are established by stone monuments set in the ground at locations convenient to the county seats in the different counties of the State. They are listed and described in Volume I of the State Survey Reports, where the following description is given:

"These monuments are four feet in length and are buried so as to leave six inches projecting, the upper surfaces being dressed to a cubical form 6 inches on a side. In the center of the northern mark is imbedded an aluminum tablet which is stamped $\frac{\text{U.} \mid \text{S.}}{\text{W.} \mid \text{Va.}}$ the center of the cross marking the northern end of the meridian line. In the center of the southern or station mark is imbedded a bronze tablet. On this is cast the legend U. S. GEOLOGICAL SURVEY, W. VA. MERIDIAN MARK. On its center is cut a true north and south line pointing to the north or distant mark, while places are provided for stamping the elevation above sea-level when they shall be determined by future surveys."

MORGAN COUNTY.

Berkeley Springs.

Location: State land adjoining the Berkeley Springs Hotel.
Station Mark: A column of limestone 36" x 6" x 6"; set 30" in ground 12 feet from fence on northeast side of ground.
Reference Mark: "Washington Elm," N. 20° E., 18 feet.
Distant Mark: North stone, limestone 6" x 6" x 36"; set 30" in ground, 300 feet north of south stone, and 14 feet west of iron gate.
Magnetic Declination: 4° 36′ W. November 21, 1897. Mean annual change, + 03′ approximately.

BERKELEY COUNTY.

Martinsburg.

Location: At head of principal drive of cemetery and 13 feet west of walk.

Station Mark: A column of marble 40" x 8" x 6"; set 32" in the ground, in center of which is a copper plate.

Distant Mark: North of station 575 feet. It is a marble column 40" x 8" x 6"; set 32" in ground, 30 feet east of the entrance gate and 4 feet from the fence. Aluminum bolt in center of stone.

Magnetic Declination: 4° 27′ W., May 27, 1898. Mean annual change, + 03′ approximately.

JEFFERSON COUNTY.

Charlestown.

Location: In corner of wall at northeast corner of M. E. Church.

Station Mark: A column of sandstone 40" x 10" x 7"; set 36" in ground, in the center of which is a copper plate.

Reference Marks: East wall of church 4.9 feet; south wall of church 10 feet; north corner of church 8.9 feet; northeast corner, 10.3 feet.

Distant Mark: North of station 767 feet. It is a column of limestone 30" x 10" x 7" set 28" in ground. Aluminum bolt in center of stone. Reference marks of same: Southeast corner of Harness Factory S. 60° E. 76.5 feet.

Resident Referee: County Surveyor.

Magnetic Declination: 3° 32′ W., June 6, 1898. Mean annual change, + 03′, approximately.

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